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How does Digital Transformation reshape the Multinationals' operations in an emerging country? An evolutionary process research

Como a Transformação Digital modifica as operações das Multinacionais em um país emergente? Uma pesquisa de processo evolucionária

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To:

the memory of my grandparents Henrique, Victória, Max e Cecília, transcontinental travelers that settled in the "land of the future,"

my mother Rachela and the memory of my father Ramiro Fisch, always ahead of their time,

my wife Célia and my son Paulo for joining and supporting me in this adventure.

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“You should use digital transformation to turn a caterpillar into a butterfly. Unfortunately, most companies will not create butterflies, but a really fast caterpillar.” - George Westerman (MIT TECHNOLOGY REVIEW, 2021)

RESUMO

Fisch, F. **Como a Transformação Digital modifica as operações das Multinacionais em um país emergente?** Uma pesquisa de processo evolucionária. 2021. 208p. Tese (Doutorado) – Escola Politécnica, Universidade de São Paulo, São Paulo, 2021.

Esta tese investiga como e por que a Transformação Digital (DT) está modificando as operações das empresas multinacionais. Os dois modelos para as redes internacionais de manufatura, aqui rebatizadas de redes internacionais internas (IINs), foram publicados nos anos 1990, mas ainda são referência para a literatura sobre gestão das operações internacionais. O primeiro modelo, de 1997, pertence a Kasra Ferdows e descreve o papel das fábricas no exterior. O segundo modelo, sobre a configuração e coordenação das IINs, foi publicado por Shi e Gregory em 1998. Usando revisão sistemática da literatura sobre Gestão de Operações Internacionais e DT e fazendo a intersecção dos resultados, extraímos os poucos artigos que abordam os dois temas simultaneamente. Nós sintetizamos três estratégias de DT, Integração, Servitização, e Relocalização, e quatro jornadas de TD, Integração da IIN, Integração do Ciclo de Vida, Servitização Capacitada Digitalmente, e Relocalização, que contrastam com os pressupostos dos modelos tradicionais e formam a base do nosso modelo analítico. Neste estudo exploratório, utilizamos a pesquisa processual evolucionária baseada em casos para investigar sete casos de cinco empresas multinacionais operando no Brasil. O período coberto nesta pesquisa se inicia logo antes da DT e se estende até o momento da pesquisa de campo. Esta tese propõe uma nova estrutura teórica que atualiza os modelos tradicionais nos níveis planta e rede, a partir das mudanças tecnológicas e organizacionais que a DT provoca nas operações internacionais das firmas. Nossa proposição inclui contribuições teóricas como a introdução da DT no campo de gestão de operações internacionais, os mecanismos que a DT promove para mudar a IIN e suas plantas, como o deslocamento de atividades do nível planta para o nível rede, a inclusão de plantas que contribuem com a rede em funções diferentes da produção, e a introdução do conceito de ecossistemas para dar suporte à descrição das complexas relações entre as unidades da rede internacional interna. Também propomos uma nova tipologia para descrever novos tipos de coordenação de rede e papéis de plantas, a Rede Interna Multinacional Habilitada Digitalmente – RIMHAD. A tese traz novas perspectivas para o entendimento de como multinacionais reorganizam suas operações, agora e no futuro, em tempos de desglobalização e pandemia. Traz também uma reflexão sobre o papel das operações de multinacionais em países emergentes como o Brasil. Para finalizar, a tese lista implicações práticas a gestores, firmas e governos.

Palavras-Chave: Empresas Multinacionais. Internacionalização de Empresas. Transformação Digital. Indústria 4.0. Digitalização.

ABSTRACT

Fisch, F. **How does Digital Transformation reshape the Multinationals' operations in an emerging country?** An evolutionary process research. 2021. 208p. Tese (Doutorado) – Escola Politécnica, Universidade de São Paulo, São Paulo, 2021.

This thesis investigates how and why Digital Transformation (DT) is reshaping multinational firms' operations. The two models addressing the international manufacturing networks, here dubbed inner international networks (IINs), were published in the 1990s but still ground the literature on international operations management. In 1997, Kasra Ferdows proposed the first model, about the roles of foreign factories. In 1998, Shi and Gregory published the second model, depicting the configuration and coordination of IINs, Using a systematic literature review about international operations management and DT and intersecting the two literature results, we extract the few articles addressing the transformations that digital technologies promote in the MNE's operations. We synthesize three DT strategies - Integration, Servitization, and Relocation - and four DT journeys – IIN Integration, Life-Cycle Integration, Digitally Enabled Servitization, and Relocation - that contrast the traditional models' assumptions and build our conceptual framework. This exploratory study uses the evolutionary process case research method to investigate seven embedded cases in five multinationals operating in Brazil. In this research, we retrospectively cover the DT's period of implementation. We propose a new framework that extends the traditional plant- and network-level models based on the technological and organizational changes that DT promotes to the firms' international operations. Our proposal includes theoretical contributions like the introduction of DT into the field of international operations management, the mechanisms DT promotes to change the IIN and its sites like the displacement of activities from the site level to the network level, the inclusion of sites that contribute to the network with functions other than production, and the ecosystem construct's introduction to support describing the complex network participants' relations. We also offer an updated typology to describe new network coordination and plant roles, the Digitally Enabled Multinational Inner Network - DEMIN. The thesis brings new perspectives for understanding how multinationals reorganize their operations, now and in the future, in times of deglobalization accelerated by pandemics. There is also a reflection about the role of multinationals' operations in emerging countries like Brazil. Finally, the thesis lists practical implications to managers, firms, and governments.

Keywords

Multinational Enterprises. Firm Internationalization. Digital Transformation. Industry 4.0. Digitalization.

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ACRONYMS INDEX

AGV	Automated Guided Vehicle
AI	Artificial Intelligence
BDA	Big Data Analytics
CBU	Completely built-up
CC	Cloud Computing
CKD	Completely knocked down
CPS	Cyber-Physical System
DEMIN	Digitally Enabled Multinational Internal Network
DT	Digital Transformation
HQ	Headquarter
I3.0	Industry 3.0
I4.0	Industry 4.0
ICT	Information and Communication Technologies
IIN	Internal International Network
IMN	International Manufacturing Network
IOM	International Operations Management
IoS	Internet of Services
IoT	Internet of Things
M&A	Merger and Acquisition
MNE	Multinational Enterprise
OECD	Organization for Economic Co-operation and Development
OM	Operations Management
R&D	Research and Development
RAMI4.0	Reference Architecture Model Industrie 4.0
SKD	Semi knocked down
USA	United States of America

SUMMARY

1 INTRODUCTION AND RELEVANCE

1.1 CONTEXT AND MOTIVATION FOR THIS RESEARCH

The Digital Transformation (DT), also known as the fourth industrial revolution or industry 4.0 (I4.0), has touched every aspect of human life (SCHWAB, 2017). DT merges the physical and digital worlds, creates new possibilities to integrate machines, men, and organizations (KAGERMANN; WAHLSTER; HELBIG, 2013; SCHWAB, 2017), and significantly reshapes the operations of firms in general (WEKING et al., 2020; YIN; STECKE; LI, 2018). There are also implications for International Operations Management (IOM) that should affect the Multinational Enterprises' (MNEs) networks of operations and plants.

Two seminal papers ground the IOM theories and models: the article by Kasra Ferdows (FERDOWS, 1997) on plant roles and the article by Shi and Gregory (1998) on International Manufacturing Networks (IMNs) that from now on in this text we will refer to as the International Inner Network (IIN). Demeter (2017) and Cheng, Farooq, and Johansen (2015) provide excellent summaries of the literature based on the models from Ferdows (1997) and Shi and Gregory (1998).

Kasra Ferdows' typology, published in the Harvard Business Review, was a simple, remarkably insightful, and robust model, resulting from the author's experience and not developed for academic validation. Many scholars replicated (VEREECKE; VAN DIERDONCK, 2002), enhanced (CHENG; FAROOQ; JOHANSEN, 2011; BLOMQVIST; TURKOLAINEN, 2019), or even criticized the model (MEIJBOOM; VOS, 2004), providing supporting literature that justifies its wide acceptance in the IOM field.

Shi and Gregory (1998) elaborated a pioneering model to describe various configurations of the IIN using two factors, the geographical dispersion of all plants and the network's coordination. Different combinations of these two factors lead to specific IIN configurations. Blomqvist and Turkulainen (2019), Cheng, Farooq, and Johansen (2011), and Feldmann et al. (2013) bridge the model from Shi and Gregory for the IIN level and Ferdows' model for the plant level by investigating what happens to an IIN configuration when one of its plants changes its role.

In emerging markets, there is a concern that DT will lead headquarters (HQ) to centralize the management of international operations, while subsidiaries will only hold production activities. This situation would centralize the coordination of the IIN and significantly reduce the roles of plants. Emerging markets would become production hubs, while all development and management activities would concentrate at the HQ located in developed countries. Investigating the accuracy of this hypothetical scenario is the starting point of our study on DT and IOM. We use Brazil as the stage for our research, given the complexity and relevance of this emerging market that hosts many operations from local and foreign MNEs.

1.2 THE RELEVANCE OF DT TO IOM

A study from McKinsey (MCKINSEY, 2018) estimates that DT affects sectors that move about 110 trillion US dollars per year, or 70% of all global trade, employing around two billion persons or 30% of the world's population. The integration of the physical and digital worlds that characterize the DT promises to change operations' logic with unprecedented productivity increases estimated on the order of billions of US dollars. The value creation for the German economy, for example, is estimated between 100 and 200 billion US dollars in five years (HERMANN; PENTEK; OTTO, 2016; SCHUH et al., 2017, 2020a). Consulting firms' projections confirm these numbers (BERGER, 2016; GATES; BREMICKER, 2017; MCKINSEY, 2018). The Organization for Economic Cooperation and Development – OECD – estimates productivity growth between 5% and 60% and financial gains of around 2 billion US dollars per year for each of the sectors evaluated in their report (OECD, 2017). Casella and Fomenti (2018) highlight the ever-increasing use of digital technologies to do business between firms and consumers, known as B2C, and between firms, or B2B. Soto-Acosta (2020) highlights the acceleration of DT in organizations because of the COVID-19 Pandemic.

The proliferation of government programs to foster their local industry reinforces the relevance of DT. Germany was one of the first countries to promote the digital economy, investing in the digitalization and interconnection of products, value chains, and business models by launching their "*Platform Industrie 4.0*" in 2011 (KAGERMANN; WAHLSTER; HELBIG., 2013). Japan implemented "*Society 5.0"* in 2016 as a strategy to transform not just production but the entire society with emerging technologies (SCHWAB, 2018a). Other examples of national development programs are "*Research, Innovation and Enterprise 2020 Plan*" in Singapore, "*Manufacturing Innovation 3.0*" in South Corea, "*Factories of the future*" in the European Union, "*Advanced Manufacturing Partnership*" in the United States of America (USA), and "*Made in China 2025*" in China; (ARBIX et al., 2017; LIAO et al., 2018).

However, the application of new technologies without a sound business justification may result in adverse effects. During the early digitation of the third industrial revolution, firms like GE, IBM, and Fiat made heavy inversions in industrial automation without considering issues like lack of flexibility or equipment failure (BRENAN et al., 2015; FLEURY; FLEURY, 2012). Another firm that misjudged trends was Olivetti, a traditional typing machine manufacturer that used new electronic technologies to build an electrical typing machine while microcomputers, text processors, and printers replaced the writing machine business (GUROVITZ, 1999). Kodak, a lead film manufacturer for the photography market, invented the digital camera but faced the consequences of ignoring the new digital technology when it replaced obsolete film cameras (LUCAS JR; GOH, 2009). More recently, the global air transportation business halted operations of the Boeing 737 Max after a series of fatal accidents caused by faulty automated systems, resulting in losses of hundreds of lives and billions of dollars to the aircraft manufacturer (ROBISON, 2019). Other risks associated with DT are the impact on the workforce and the organization of work, and the fragility and safety of complex cyber-physical systems, depicted in a recent OECD report (OECD, 2017).

Opportunities and risks from DT stand from the fact that the traditional economy considers production as a critical factor for organizing operations (DUNNING, 1988), while data becomes an essential factor for the digital era (ECONOMIST, 2017), a significant change to MNEs (CULOT; ORZES; SARTOR, 2019). The models from Ferdows and Shi and Gregory acknowledge production but ignore data. Consequently, they may not capture novel ways that MNEs can choose to integrate functions and processes, relocate operations, and offer new solutions to their clients in the form of intelligent products and services. Therefore, it is of utmost importance to comprehend how DT will impact IOM (BRENNAN et al., 2015; KETOKIVI et al., 2017; STRANGE; ZUCCHELLA, 2017).

1.3 RESEARCH PROBLEM AND RESEARCH QUESTION

IOM and DT are well-researched subjects, but surprisingly their intersection is scarce and underexplored. Using Scopus database searches, we identified 3,221 articles related to IOM and 7,523 articles on DT in February 2021. There are relevant literature reviews in IOM (CHENG; FAROOQ; JOHANSEN, 2015; CHENG; FAROOQ, 2018; DEMETER, 2017; PASHAEI E OLHAGER, 2017) and DT (ALCÁCER; CRUZ-MACHADO, 2019; FRANK; DALENOGARE; AYALA, 2019; LIAO et al., 2017; RODRIGUES; DE JESUS; SCHÜTZER, 2016; THOBEN; WIESNER; WUEST, 2017; XU; XU; LI, 2018) that we use as sources to build the theoretical reference in this work. Nevertheless, the combination of the two separate searches above mentioned provides only ten relevant results, Brennan et al. (2015), Culot, Orzes, and Sartor (2019), Fisch and Fleury (2020), Garay-Rondero et al. (2019), Hannibal (2020), Seino (2019), Strange and Zucchella (2017), Szalavetz (2019, 2020), and Telukdarie et al. (2018). This result is unexpected, as Kagermann, Wahlster, and Helbig (2013) envisioned an integrated network of plants, functions, and external partners in their seminal work that coined the term *"Industrie 4.0".*

While *data* is the new key factor that drives DT, *integration* is its keyword (KAGERMANN; WAHLSTER; HELBIG, 2013). Integration can be horizontal across the entire supply chain, vertical from the production floor digital systems through enterprise resource planning, across MNE's functions, or along the life cycle of a product or service (ADOLPHS et al., 2015). For example, Telukdarie et al. (2018) describe a digitally integrated global maintenance system with higher productivity than a traditional local system. The acceleration of servitization offers traditional manufacturers the opportunity to evolve into service providers and reorganize their IINs, thanks to intelligent products (BRENAN et al., 2015; CULOT; ORZES; SARTOR, 2019; SEINO, 2019). DT also promotes the relocation of operations from low-cost to close-to-market locations due to higher agility demands from customers and the availability of technologies that lower the production costs, reversing the offshoring typical of the third industrial revolution (BARBIERI et al., 2018; BRENAN et al., 2015; DEMETER, 2017; KINKEL, 2012; STRANGE; ZUCCHELLA, 2017). The above texts provide good descriptions of DT-related phenomena. Nevertheless, they lack a more in-depth explanation of how and why DT leads to a redesign of the international operations of MNEs, the research problem of this thesis, and the basis to the following research question:

“Why and how does DT rearrange the configuration of the IIN and the roles of its plants?”

1.4 RESEARCH OBJECTIVES

Our research question focuses on DT processes that lead MNEs to evolve their operations from early digitation to the digital era. In this study, we will explore the limits of Ferdows` and Shi and Gregory’s typologies and build a new framework more apt to describe international operations' features in the digital era – the Digitally-Enabled Multinational Inner Network (DEMIN). We will adopt the term Inner International Network (IIN) for the range of home and foreign production units of an MNE. We assume that the IIN is broader than the International Manufacturing Network (IMN), thus reflecting the integration of different functions as part of the DT process. The IIN reinforces the notion that manufacturing comprehends more than just the production function, including others like Research and Development (R&D), service delivery, logistics, marketing, sales, and administrative functions, in line with the definition from Fleury and Fleury (2012), Rugman, Verbeke, and Yuan (2011) and Skinner (1969).

When an MNE triggers a DT process, it reorganizes work processes creating new configurations inside the IIN and new roles for its plants through function integration and expansion of its business and innovation ecosystems. DT improves productivity, promotes closer contact with clients and stakeholders, and increases the innovation capability using internal and external partners. The results achieved are beyond those obtained with early digitation and connectivity, typical from the third industrial revolution. Digital twins and digital platforms provide real-time update of both integrated physical and digital systems allowing fast analysis, problem or opportunity identification, scenario simulations, and adaptability to changes at unprecedented speed and accuracy (GAWER, 2014; GAWER; CUSOMANO, 2014; LEE; BAGHERI; KAO, 2015; SCHUH et al., 2017, 2020a). There are consequences to the interaction among plants inside their respective IINs, resulting in a rebalancing of the centralization and dispersion forces described by Dunning (1998) and Porter (1990). MNEs can, therefore, assume new configurations for their IINs and assign new roles to their plants by integrating functions through servitization or by relocating operations and activities to cope with the new capabilities provided by DT. By doing so, they intend to improve their competitiveness and productivity.

The following specific objectives support the main research question of this thesis:

a. Understand how MNEs develop DT strategies and implement DT journeys.
b. Describe DT's implications to the IIN's configuration and its plants' roles.
c. Learn how subsidiaries and operations evolve with DT in an emerging market.

1.5 RESEARCH PROJECT

The research project investigates how and why a nascent process – the DT (FRANK; DALENOGARE; AYALA, 2019; VIAL, 2019) coevolves with IOM transforming the classical models from Ferdows (1997) about plant roles at the plant level and Shi and Gregory (1998) of IIN configurations at the network level of MNEs. We develop brief reviews of both IOM and DT fields of research and then use the few reference articles that attempt to bridge the two subjects as a basis to build our arguments and the research framework. For this study, we use Brazil's operations, an emerging market, and look at two analysis levels – the plant and the IIN. We start from models in the academic literature and transition between the theory and empirical worlds to build our final conceptual framework. Therefore, our qualitative research is exploratory and abductive (KETOKIVI; CHOI, 2014; VOSS; JOHNSON; GODSELL, 2015, 2016).

We use processual evolutive case studies to conduct the research (LANGLEY,1999; ABDALLAH; LUSIANI; LANGLEY, 2019). Given that DT is a new and unknown complex process, our sampling aims at providing a comprehensive view of the industry. We selected firms from different sectors involving several types of products, service offerings, and manufacturing processes. Complementarity across cases is the driver of our sampling. The main comparison occurs in the longitudinal dimension, in line with the processual methodology (LANGLEY, 1999; ABDALLAH; LUSIANI; LANGLEY, 2019), instead of across cases as expected in the configurational comparative analysis tradition from Eisenhardt (1989) and Yin (2015). We collect data from sources like semi-structured interviews, websites, academic and business literature, and documentation shared during site visits. We codify and analyze data using the guidelines from Gioia, Corley, and Hamilton (2013) and Strauss and Corbin (1990, 2008). Although created for grounded theory, these guides represent an effective way to identify “surprises” and insights essential to theory construction (EISENHARDT, 1989; LINNEBERG; KORSGAARD, 2019). Miles, Huberman, and Saldaña (2014) provide an additional reference for coding and displaying results both in narrative and table forms.

1.6 THEORETICAL CONTRIBUTIONS

Whetten (1989) describes four essential elements of a theory, a) “what,” the “boxes” in a diagram or the constructs, concepts, variables that take part in the phenomenon’s explanation, evaluated by their comprehensiveness and parsimony, b) “how” representing the relationships among the “whats,” or the “arrows” in a diagram, c) “why,” the rationale explaining the reasons to organize the “boxes” and “arrows” of the diagram, and d) “who/where/when” that limit the applicability of the proposed theory to specific temporal and contextual factors. The theoretical framework consists of “whats” and “hows,” “whys” are a plausible explanation, and “who/where/when” define the theory’s boundaries (WHETTEN, 1989).

This work's first theoretical contribution is adding the DT to IOM’s traditional models to unveil the mechanisms that explain the reshaping of the IIN’s configuration and its plants’ roles. Proposing new typologies to the existing models is the second theoretical contribution. Clarifying what happens to operations in emerging markets is our third intended contribution. MNEs operating in Brazil provide two boundaries to our research, *MNEs* representing the “who” and *Brazil* representing the “where.” We use a longitudinal approach to limit our research’s temporal aspect to two moments, the first before starting DT processes and the moment of our data collection. We also intend to unveil details about the DT process for future research since we expect our cases to use different DT journeys and be at various DT implementation stages.

Corley and Gioia (2011) categorize theoretical contributions in two dimensions, originality that they divide into incremental or revelatory, and utility that may be practical, scientific, or a combination of both. This research advances the knowledge about IINs and unveils how production and data integrate operations in novel ways to form the digital-age IIN. It is original as it elaborates on classical IOM models and useful for both researchers and practitioners.

1.7 STRUCTURE OF THE THESIS

In Chapter 2, we start by describing the methodology to execute the literature review. We then build our conceptual framework by reviewing the literature covering the existing theories about IOM and DT and defining constructs like the MNE, the IIN, the IIN configuration, the site role, the digital transformation, and its main components DT strategy and DT journey.

Chapter 3 describes the research project for our study, including the context of the research, the selection of the research method, the methodologic approaches, choices, and tools we use to select the sources of data, collect data in the field and from secondary sources, analyze and interpret data, check reliability and validation, and build the research protocols and reports.

In Chapter 4, we analyze our findings from the field research. Section 4.1 assesses the internal validity of DT strategies and DT journeys, discussing common evolutionary paths. Section 4.2 discusses the evolution of the IINs under DT, while in Section 4.3, we evaluate the development of the plants with DT, presenting the DEMIN model.

Chapter 5 concludes the work by presenting the contributions to theory and practice, pointing limitations, and suggesting future research opportunities.

Appendix A contains the research protocol, including the research instrument.

Appendix B shows the questionnaire for Case A’s second round of interviews, developed specifically to cover the gaps from the first round of interviews.

In Appendix C, we display the coding summary of the field research.

Appendix D presents the individual case summary reports.

2 LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, we review the literature to build our conceptual framework. We briefly introduce the structure of the literature review in this section. In Section 2.2, we describe the methodology of the literature review. The literature review has three main parts. In the first one, Section 2.3, we review the literature that addresses the Multinational Enterprise (MNE). We start with a definition for the Multinational Enterprise (MNE) and its main characteristics (FLEURY; FLEURY, 2012; RUGMAN; VERBEKE, 2001). We discuss the evolution of internationalization theories of the MNE and its main drivers, as well as the shift in the focus from the firm level to the subsidiary level as described by Rugman, Verbeke, and Nguyen (2011), recognizing the importance of not just the HQ, but also operations at host countries. In section 2.4, we introduce the study of MNEs in IOM. We present the two perspectives used in IOM - external versus internal (RUDBERG; OLHAGER, 2003) and explain why we select the internal view to develop this work. Our literature research discusses the IIN at the network and plant levels. We present the literature on the IIN level, based on the seminal model from Shi and Gregory (1998), and the plant level based on the model from Ferdows (1997). Finally, we discuss how the IOM literature integrates these two levels of analysis.

The second part of the literature review starts in section 2.5, where we address terms like the fourth industrial revolution and I4.0 to develop our working definition of DT as a process in IOM. We also introduce a framework based on Vial (2019) to build our conceptual framework. In section 2.6, we present DT's technological and organizational dimensions, recognizing that technology alone is not enough to promote DT (SCHUH et al., 2017, 2020a; SCHUMACHER, EROL, SIHN, 2016).

The third part presents the scarce intersections of the IOM and DT literature, in line with the prospector's blending and merging approach (BRESLIN; GATRELL, 2020). In Section 2.7, we review how IOM and DT literature defines the DT strategy for MNEs. Section 2.8 analyses evidence on different paths or DT journeys that MNEs take to implement their DT strategies. We close Chapter 2 by presenting the analytic framework for this research to study the evolution of the IIN's configuration and plant roles with DT in Section 2.9. Our model proposes that MNEs implement their DT strategies through DT journeys, provoking technological and organizational changes to reshape the IIN and its sites.

2.2 METHODOLOGY FOR THE LITERATURE REVIEW

Relevant literature reviews cover the research subject of IOM and IIN (CHENG; FAROOQ; JOHANSEN, 2015; DEMETER, 2017; PASHAEI; OLHAGER, 2017). The OM research field also presents excellent reviews about I4.0 and DT (ALCÁCER; CRUZ-MACHADO, 2019; LIAO et al., 2017, 2018; RODRIGUES; DE JESUS; SCHÜTZER, 2016; THOBEN; WIESNER; WUEST, 2017; XU; XU; LI, 2018) We use them to identify the most relevant papers in each area. We extract the current extant definitions with their contexts, discuss, select, and justify the constructs for building the theoretical reference in this work.

We then look at the intersection of IOM and DT, our two emerging areas of interest, following the guidelines from Tranfield, Denyer, and Smart (2003) to plan, execute, and report, and Zupic and Čater's (2015) five-step approach adapted to our objective to build the theoretical framework: (a) research design to select the proper subject, knowledge base, and appropriate search method that we covered in the introduction of this work, (b) compilation of bibliometric data to select or build the proper database and filtering criteria that we introduce in the next paragraph, (c) analysis involving the selection of bibliometric tools, cleaning of data, execution of the selected search method, identification of the leading research streams, their constructs and respective definitions, (d) visualization of extracted data to highlight the importance and centrality of the selected papers, and (e) interpretation, where we discuss and justify the selection of constructs, definitions, and statements that will form our conceptual framework.

We selected the Scopus database for our systematic literature reviews. The search for each of the sections below proceeded according to the following steps: (a) selection of keywords, (b) search in the Scopus database, (c) screening by type of publication including only articles, reviews, and editorials, (d) screening by interest areas like Engineering, Business, Economics, Decision Sciences, and Social Sciences, (e) if the resulting list was above 200 articles, identification of relevant bibliometric or literature review articles by citation and/or selection of outlets listed in the Academic Journal

Guide 2018 from the Association of Business Schools (CHARTERED ASSOCIATION OF BUSINESS SCHOOLS, 2018), (f) review of titles and abstracts to exclude papers not related to the subject of interest, (g) analysis using the Scopus database tools to select the most cited articles (h) export of the list of items to excel and adjustments for further processing, (i) keyword and co-citation analysis using the VOS software to identify significant keywords and reference articles for subsequent analysis, (j) determination of centrality and betweenness articles using Ucinet software, (k) selection of the papers used in the literature review as the most cited, most central and connective to the subject, most co-cited, as well as screening of recent articles from the last 3 to 5 years that we found worth using in the analysis, (l) reading each selected article, extracting relevant data, (m) writing the literature review, and (n) defining the constructs based on the literature review and research objectives.

2.3 DEFINING THE MNE AND ITS OPERATIONS

According to Fleury and Fleury (2012), the literature provides several definitions to an MNE, highlighting foreign direct investments and operations in more than one country. For example, Pearce (2018, p. 10) defines an MNE as “a firm that owns or controls value-adding activities in two or more countries.” Rugman and Verbeke (2001:238) provide a broader definition for the MNE as:

> “a differentiated network of dispersed operations, with a configuration of competencies and capabilities that cannot be controlled fully through hierarchical decisions about foreign direct investment taken by corporate headquarters.”

There are three distinctive characteristics of this definition that support our research: (i) a dispersed network of operations, (ii) a configuration of competencies or activities, and (iii) an association to an internationalization strategy. Several traditional theories from economic geography and international business developed between the 1960s and 1980s describe one or more of these three characteristics, starting with the dissertation from Stephen Hymer in 1960, the first work to study the MNE as an organization designed for international production (RUGMAN; VERBEKE; NGUYEN, 2011), the product life cycle theory from Vernon (1966), the incremental expansion from Johanson and Wahlne (1977, 2009), the internalization theory from Peter Buckley and Mark Casson (BUCKLEY, 2014; BUCKLEY; CASSON, 1976, 1998), the eclectic paradigm from John Dunning (DUNNING, 1977, 1988, 1998, 2001), and the Firm-

Specific and Country-Specific Advantages from Alan Rugman and Alain Verbeke (RUGMAN; VERBEKE, 1992, 2001, 2003). In common, these theories consider the MNE as the object of study. In the 1990s, two models recognize different roles for the subsidiaries of the MNE.

By the study of strategic approaches to internationalize, Bartlett and Ghoshal (1986, 2002) identify four different organizational models for subsidiaries depending on the strategic importance of the location and the local level of resources and competencies: (a) the implementer for places with low strategic importance and low level of competencies, (b) the contributor for locations with low strategic importance and high level of competencies, (c) the black hole for places with high strategic importance and low level of competencies, and (d) the strategic leader with both high strategic importance and level of competencies. Although Bartlett and Ghoshal still use the MNE as a unit of analysis, they recognize that subsidiaries are not all the same.

Julian Birkinshaw introduced the subsidiary as the unit of analysis in the study of MNEs, proposing a typology that represents different capabilities to make decisions and innovate inside the network composed of the MNE's HQ and its subsidiaries (BIRKINSHAW, 1996,1997; BIRKINSHAW, MORISSON, 1995; BIRKINSHAW; HOOD, 1998; RUGMAN; VERBEKE; NGUYEN, 2011). Birkinshaw and Morrison (1995) present a typology based on the subsidiary's capabilities and performance and the relationship with the HQ and other subsidiaries in the network. The typology consists of three types of subsidiaries: (a) the local implementer, limited in scope and autonomy, (b) the specialized contributor that holds expertise in a limited range of activities and a high level of interdependence with its counterparts, and (c) the world mandate having global or regional responsibility for an entire business or product line (BIRKINSHAW; MORRISON, 1995).

Birkinshaw (1997) further explores these subsidiaries' initiatives that can be local or global in their scope and internal or external to the MNE in their nature, set by the subsidiary or by the HQ. According to Birkinshaw (1997), subsidiaries can learn, react locally, and integrate globally, in a way that will lead them to increase their value inside the MNE's network or, else face the risk of losing relevance, competencies, or even their strategic motivation (BIRKINSHAW, 1996, 1997; BIRKINSHAW; MORRISON, 1995). Birkinshaw and Hood (1998) explore the several paths a subsidiary can evolve based on changes in their actual capabilities and their charter, or the activities that the

MNE entitles them to execute. Differentiating between the capabilities available at a subsidiary and the activities they have the mandate to manage is essential to the critique of the model by Ferdows (1997) that we will cover when discussing IOM in the next section.

In common, Bartlett and Ghoshal (1986), Birkinshaw (1996, 1997), and Birkinshaw and Morrison (1995) use two dimensions to characterize subsidiaries, one locational and one capability related. These dimensions serve as a basis for two seminal models in IOM, the configurations of the IMN from Jongjiang Shi and Mike Gregory (SHI; GREGORY, 1998) and the plant roles of international factories from Kasra Ferdows (FERDOWS, 1997) that we present in the next section.

2.4 IOM AND THE INNER INTERNATIONAL NETWORK

2.4.1 External and internal approaches to IOM

OM is an old area of practice, although young as a research area born in the 1980s (CHENG; FAROOQ; JOHANSEN, 2015; DEMETER, 2017). Initially focused on the activities and responsibilities assigned to each plant geographically set apart, early OM studies have roots in Skinner's seminal paper about manufacturing operations inside the factory (SKINNER, 1969). Roger Schmenner recognizes the notion that firms use a strategy to distribute their responsibilities to several plants in a paper that proposes different strategies for companies owning multi-plant manufacturing systems (SCHMENNER, 1982; CHENG, FAROOQ; JOHANSEN, 2015). Globalization in the 1980s and 1990s accelerated the dispersion of manufacturing with increasing management complexities that led IOM to extend the study of MNEs' operations from a multi-factory perspective to a network perspective (RUDBERG; OLHAGER, 2003).

Rudberg and Olhager (2003) argue that the activities of MNEs take place in value networks with two different perspectives, the external network of the supply chain from logistics management and the internal network of the manufacturing network of OM. The supply or value chain/network perspective for manufacturing a product uses the Global Production Network from economic geographers (COE; DICKEN; HESS, 2008; HENDERSON et al., 2002). Henderson et al. (2002) expand the Global Value Chain framework (GEREFFI; HUMPHREY; STURGEON, 1995) by considering governance issues among the firms and institutions from a network instead of the dyadic governance typology of the Global Value Chain. IOM uses this type of network to study supply chain and logistics issues, considering manufacturing as a sort of "black box" (RUDBERG; OLHAGER, 2003). Two relevant examples are papers on knowledge transfer inside Global Production Networks from Dyer and Nobeoka (2000) and Ernst and Kim (2002), involving manufacturers and their suppliers.

The IIN represents the internal perspective to look at the activities of the MNE. Cheng, Farooq, and Johansen (2015, p.393) define the IIN as: "a coordinated aggregation (network) of intra-firm plants located in different places." We adopt the internal perspective and use this definition in our research because it highlights an approach that associates structural and infrastructural decisions at the plant level with configuration issues decided at the network level (DEMETER, 2017). The use of the broader definition of manufacturing, as we explained in section 1.4, implies that a plant in the IIN may execute one or several manufacturing activities that may or may not include production, a difference to the IMN construct that only considers factories with production activities.

2.4.2 The network and plant perspectives to the Inner International Network (IIN)

Cheng, Farooq, and Johansen (2015) and Demeter (2017) identify two central units of analysis in their literature review on IINs – the network and the plant. The network-level literature builds on the model proposed by Shi and Gregory (1998), where two dimensions characterize the IIN, (a) the geographic dispersion of plants or the IIN's configuration and (b) the degree of centralization of activities, or the IIN's coordination. The landmark of the plant-level literature is Ferdows (1997), whose model consists of a plant typology based on different combinations of the strategic reason to locate a plant and its competencies or activities. The main advantage of the IIN-level approach is that it offers a network-wide perspective of the potential advantages and capabilities of the entire network, while the plant-level approach allows researchers to evaluate different characteristics of individual plants that form the IIN (CHENG, FAROOQ; JOHANSEN, 2015). In our research, we use both levels of analysis in the same way as Blomqvist and Turkulainen (2019), Cheng, Farooq, and Johansen (2011), and Feldmann et al. (2013).

2.4.3 The Network level of analysis to study IINs

Several models use the network-level analysis for IINs, but most of them address either the network's physical configuration or coordination (CHENG, FAROOQ; JOHANSEN, 2015). An example is Schmenner (1982) that explores configuration but not coordination aspects when presenting his typology for multi-plant organizations based on different strategies – product, market area, process, and multipurpose. We will return to this model in section 2.7. Colotla, Shi, and Gregory (2003) refer to the model by Porter (1986) to evaluate the competitive advantage based on (a) configuration, defined by the locations of the network executing activities, and (b) coordination that refers to how the network links and manages these activities.

The paper by Shi and Gregory (1998) is the most cited reference of network-level analysis for the study of IINs. Their IIN model unites the individual factory system model from Hayes and Wheelwright (1984) to networks from Porter's firm strategy model (1980). The model uses the structural (e.g., capacity, facilities, technologies) and infrastructural elements (e.g., workforce, quality, production, planning, and materials controls) of the individual factory, adding network features like the geographic dispersion of plants and coordination mechanisms (SHI; GREGORY, 1998; COLOTLA; SHI; GREGORY, 2003).

Shi and Gregory (1998) attribute the geographical dispersion to the growth of markets and access to strategic resources, suggesting that the IIN must implement coordination mechanisms as soon as a firm leaves its domestic market to set operations abroad. The geographic dispersion or configuration of a network can be: (a) domestic, with operations in the home country serving local and export markets; (b) regional, covering a limited geographic area typically with small cultural distance from the home country; (c) multinational, dispersed in several regions and manufacturing concentrated in few countries; or (d) worldwide with many manufacturing operations in countries around the world. (SHI; GREGORY, 1998).

There are two modes of coordination in the model from Shi and Gregory, (a) the multi-domestic, where each unit enjoys a high degree of autonomy and the network has weak coordination, and (b) the globalized, where network coordination is strong with central management and limited autonomy for the units in the network. Combinations of configuration and coordination result in four types of networks, depicted in Table 1 (SHI; GREGORY, 1998).

Table 1 - IIN configurations

Plants' dispersion degree	Coordination conditions in the IIN	
	Multi domestic orientation Manufacturing system tailoring to the local market with high autonomy. Weak coordination, independent factories	**Global orientation** Global-oriented strategies with an integrated and coordinated network. Interdependence takes place by system design or dynamic operational mechanisms.
Worldwide and Multinational	***Multi domestic Autonomy Networks*** IIN is present in several countries; subsidiaries have a strong market focus, plants have local management with high autonomy.	***Global Coordination Networks*** IIN is present in several countries, standardized products, facilities, technologies, and systems. Dispersed Supply chains for resources optimization
Local and Regional	***Regional Focus Networks*** IIN dispersed in one Region, plants tailored to the local or regional market. No coordination between plants	***Global Export Networks*** IIN focuses on a region, but products could reach the global market with international logistics.

Source: Adapted from Shi and Gregory, 1998

The IIN provides the MNE the following strategic advantages, according to Shi and Gregory (1998): (a) strategic access to markets and resources, (b) thriftiness ability or economies of scale and scope, (c) mobility or higher flexibility in the allocation of manufacturing capacity and resources, and (d) higher learning and knowledge sharing capability inside the network. Multi-domestic autonomy and regional focus networks are more flexible to attend markets that demand local products, while the global coordination and global expert networks count on standard products across all markets.

The degree of physical dispersion depends on the specific markets where the IINs are present. Although particularly useful to study the IIN as a network of plants and operations, the model has limited power to explain individual plants' specific roles. Colotla, Shi, and Gregory (2003) try to offset this by using the Resources-Based Theory (Barney 2001) to link individual plants and competitive network advantages in a single model. Nevertheless, they still see plants as a production "black box," measured by typical production metrics like volume, cost, and quality. There is no analysis of higher-order activities like R&D or product management in the model. For that purpose, we need the plant level of analysis that we cover in the next section.

2.4.4 The Plant level of analysis to study IINs

According to Cheng, Farooq, and Johansen (2015), the models from the international business on the strategic roles, or mandates, of national subsidiaries (BARTLETT; GHOSHAL, 2002; BIRKINSHAW; MORRISON, 1995) served as a starting point for Kasra Ferdows to introduce the concept of plant roles (FERDOWS, 1997). Ferdows (1997) proposes a framework and plant role typology that enjoys wide recognition in the IOM literature (CHENG; FAROOQ; JOHANSEN,2015; DEMETER, 2017). One highly cited example is Vereecke and Van Dierdonck (2002) that use case studies to test and validate the model, proposing a few adjustments to Ferdows' typology. A second example is Meijboom and Vos (2004), who review the literature on the construct "site competence" to build a precise definition of the term and test it using cases from Dutch-owned plants in Poland and Hungary. Feldmann and Olhager (2013) present a comparison chart of several papers in the literature that provide empirical support to Ferdows' typology.

Like Birkinshaw and Morrison (1995), Ferdows (1997) considers the geographic dispersion from Shi and Gregory (1998) as the collection of strategic reasons for locating each site, while the competencies or activities that each plant executes characterizes the coordination of the IIN. Different combinations of these two factors determine the plant role within the IIN. The first factor addressed by Ferdows (1997) is the strategic reason for site location. The author lists three main reasons that justify the location of a plant. The first one is access to low-cost production sites, a significant driver for offshoring operations in the second half of the 20th century (KINKEL, 2012). The second is the access to knowledge and capabilities, a driver that gained impulse with the rise of emerging market MNEs (FLEURY; FLEURY, 2012). Finally, the third reason identified by Ferdows (1997) is the proximity to markets. Feldmann and Olhager (2013), Feldmann et al. (2013), and Vereecke and Van Dierdonck (2002) empirically test and validate the three strategic reasons for Site location proposed by Ferdows (1997) through factorization of several different potential motivators they find in the literature, for example: overcome trade barriers, take advantage of low-cost labor, capture/maintain market share, availability of workers, close to major competitors, managerial/organizational skills, proximity to raw materials, proximity to cheap energy, and socio-political climate, among others.

Regarding “competencies or capabilities,” Ferdows (1997) proposes a hierarchy of activities that alien plants can execute, calling them “competencies.” The lowest level of competence is “production,” while the upper level is the “global hub for product or process knowledge.” Intermediate levels consider competencies like technical process, procurement, logistics, supplier’s development, process recommendations for development and improvement, product development, and global market supply. Researchers critique the hierarchy of competencies from Ferdows in several ways: he uses the terms “activity” and “competency” interchangeably, the classification lacks empirical evidence, and there are plants that retain higher responsibilities without necessarily executing lower ones (VEREECKE; VAN DIERDONCK, 2002). Concomitantly, case research and interviews with academics and practitioners from actual IINs provided further empirical evidence to proposals for the hierarchy of activities (FELDMANN; OLHAGER, 2013; MEIJBOOM; VOS, 2004; VEREECKE; VAN DIERDONCK, 2002). Table 2 presents a list of articles that refer to the proposals from Feldmann and Olhager (2013), Ferdows (1997), Meijboom and Vos (2004), and Vereecke and Van Dierdonck (2002).

Table 2 - Articles using the “activities” hierarchy from four references

Author	Articles that use the “activities” hierarchy
Ferdows (1997)	Cheng Farooq and Johansen (2011) ; Feldmann and Olhager (2013); Fusco and Spring (2003); Maritan, Brush, and Karnani (2004); Meijboom and Voordijk (2003); Meijboom and Vos (2004); Vereecke and van Dierdonck (2002); Vereecke, Van Dierdonck and De Meyer (2006).
Vereecke e Van Dierdonck (2002)	Feldmann and Olhager (2013); Fleury et al. (2015); Brennan and Vecchi (2017); Ferdows, Vereecke, and De Meyer (2016); Demeter (2017); Ketokivi et al. (2017); Cheng and Farooq (2018).
Meijboom e Vos (2004)	Cheng, Farooq, and Johansen (2011, 2015); Feldmann and Olhager (2013); Demeter (2017); Cheng and Farooq (2018).
Feldmann e Olhager (2013)	Cheng, Farooq, and Johansen (2015); Demeter (2017); Ketokivi et al. (2017) Cheng and Farooq, 2018.

Source: the author

In the end, even if the hierarchy of activities varies from author to author, the first level is always production, followed by local management, whereas development for the entire network (FELDMANN; OLHAGER, 2013) is always at the highest-level competency. We will use the term “activity” for actual tasks the site executes, while “competency” refers to an existing capability that the site possesses, in line with the discussions about the two constructs from Birkinshaw and Hood (1998), Vereecke and Van Dierdonck (2002), and by Colotla, Shi and Gregory (2003).

Table 3 – Hierarchy of Activities

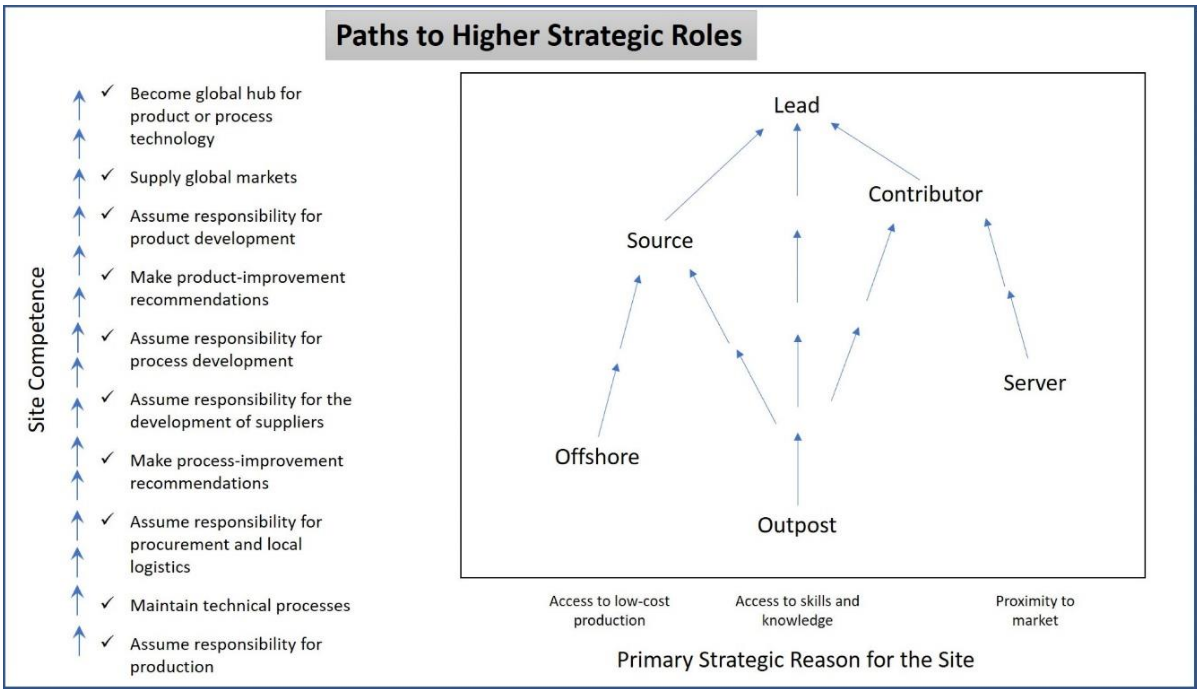
Reference article “CONSTRUCT”	ACTIVITIES
Ferdows (1997) “COMPETÊNCY”	a) Responsibility for production. b) Maintenance of technical processes. c) Responsibility for procurement and local logistics. d) Recommendations for process improvements; e) Development of suppliers. f) Development of processes. g) Recommendations for product improvements. h) Development of products. i) Supply of global markets j) A global hub for product or process knowledge.
Vereecke and Van Dierdonck (2002) “STRATEGIC ROLE”	a) Make products. b) Develop and improve systems, processes, and products. c) Hub for the development of specific important components, products, or processes. d) Development and contribution to the company’s knowledge. e) Center of Excellence – partners with the HQ in building strategic competencies.
Meijboom and Vos (2004) “PLANT COMPETENCY”	a) Production. b) Production Orders. c) Simple recommendations to improve products and processes. d) Responsible for procurement and local distribution. e) Production planning. f) Development of simple processes. g) Development of simple products. h) Complex recommendations for product and process improvement. i) Development of complex processes. j) Development of complex products. k) Creation of new processes and products for the entire company.
Feldmann and Olhager (2013) “PLANT COMPETENCY”	a) Production. b) Maintenance c) Procurement d) Logistics e) Development of suppliers. f) Development of products. g) Global sourcing. h) Introduction of new product technologies. i) Introduction of new process technologies.

Source: The author

Table 3 provides the scales presented by each of the four reference articles from Table 2. The comparison highlights that the four scales follow a similar hierarchy logic of increasing complexity, breadth, and depth of activities, starting with production and ending with some reference activity for the entire network.

Despite the controversy on the “activities” dimension, the Ferdows’ typology for plant roles still prevails in the IOM literature. Based on the combination of the strategic reason to locate and the capabilities found in a plant, Ferdows (1997) presents a typology of plant roles composed of six different types, depicted in Figure 1.

Figure 1 - Ferdows’ Typology



Source: Ferdows (1997)

The types of plants that have a primary strategic reason to locate based on access to low-cost production are Offshore and Source Plants (Ferdows, 1997). Offshore Plants assume responsibility for production only. They consist of intensive labor and local production management activities. Procurement of materials, production planning, product, and process development, are executed elsewhere in the IIN. The lower production cost compensates for overseas coordination disadvantages, like delays in communication and decision-making and higher inventories. By progressively assuming other responsibilities like process, procurement, logistics, simple process, and even product improvement recommendations, Offshore Plants can upgrade to Source Plants. This arrangement overcomes Offshore Plants’ coordination disadvantages at the cost of expensive resources at Source Plants (Ferdows, 1997).

Server and Contributor Plants locate next to markets. They differ from the low-cost operations because they are in touch with the markets they serve, therefore more sensitive to local adjustments to products (Ferdows, 1997). Server Plants typically focus on local production and may enjoy some freedom to adapt products to local markets. Contributor Plants locate in strategic markets and have proximity with the leader of the IIN, usually contributing to the product, process, and system upgrades.

Outpost and Lead Plants seek access to skills and knowledge. They locate in knowledge-intensive areas, close to universities, suppliers, and technical centers. Outposts always have a secondary reason to locate because all plants should have production activities to belong to the IIN, a characteristic of models built in the Industry 3.0 (I3.0) environment. The last plant type in the model, the Lead Plant, has the highest Site competence and activities level. The Lead Plant is a global hub for process and product knowledge (Ferdows, 1997).

Ferdows also speculates on the several ways firms can gain relevance inside their IIN, typically by gaining competencies and adding activities to their responsibilities. An example of this dynamic is Fusco and Spring's (2003) work about factories in the Brazilian automotive sector that started as low capability offshore and server factories but evolved to a source, contributor, and even lead roles in a span of ten years. However, Ferdows (1997) is not the only model for plant-level analysis in IOM. The following paragraphs present other models and justify the model selection for this thesis.

Vereecke, van Dierdonck and De Meyer (2006) build their typology of plants in the IIN by using knowledge flows, arriving at four types of plants: (a) the "Isolated" plant has limited participation in the IIN and is very autonomous; (b) the "receiver" plant is a local plant that depends on the HQ or on other plants from the IIN to survive; (c) the "hosting network player" plant is typically a "mother plant," an older plant closer to HQ or to a cluster of plants that other plants see as a reference of competencies to the IIN; finally, the (d) "active network player" plant is a center of excellence, works as a "specialist," and pilots new products and processes for the IIN. Verecke, van Dierdonck and De Meyer (2006) acknowledge that their typology is "static" and does not discuss the network's evolution, except for isolated plants' risks to lose relevance and eventually disappear. In this sense, it differs from the model of Ferdows that is "dynamic" in nature, allowing plants to evolve by seeking new capabilities to upgrade their roles.

More recently, Blomqvist and Turkulainen (2019) review Ferdows' typology using case research and a multi-level approach combining the plant and the network levels of analysis. Blomqvist and Turkulainen (2019) use the degree of dependence of the plant to the other IIN plants and the competence requirements at each plant to propose four types of plants: a) Lead plants with high competence requirements, low dependence, and global, regional, or product focus, b) Generalist plants with lower competence requirements and degree of dependence, equivalent to the source and contributor roles from Ferdows, c) Special Task plants with high competence in either process, product or sourcing, and high degree of dependence of other plants in the IIN, and d) Dependent plants with low competence and high dependent plants, equivalent to Ferdows' Server, and Offshore plants. The degree of dependence dimension supports building a model of coordination for the IIN.

Blomqvist and Turkulainen (2019) bring some interesting insights. They point out that each role in Ferdows' model is not homogeneous. Digital technologies could concentrate activities into a single site, and external plants could play an essential role in the IIN. Nevertheless, Blomqvist and Turkulainen recognize that their model is static, although IINs and their sites continuously evolve. Considering we intend to study the evolution of IINs with DT, we will use Ferdows (1997) as our primary model for the plant-level analysis of IINs.

2.4.5 Integrating the plant and the network levels for research on IINs

Multi-level research occurs because there are strong interactions between the IIN and its plants. In this section, we present integrative models and papers that address multi-level research on IIN. Maritan, Brush, and Karnani (2004) use Ferdows' model to demonstrate that the IIN coordinates plants differently according to their roles, in the first attempt to link the IIN level to the plant level found in the literature. Miltenburg (2009) makes use of the plant level model from Ferdows (1997) and the IIN level model from Shi and Gregory (1998) to build his model. Miltenburg (2009) intends to predict the configuration of the network and the role of its plants based on strategies for international manufacturing, the four strategic capabilities of the IIN identified by Shi and Gregory (1998) already presented in section 2.4.3, and the use of structural and infrastructural levelers to adjust the network aiming at optimal results. Miltenburg's

(2009) model connects the network and plant levels through the strategy, serving as a starting point to Fleury et al. (2015).

Fleury et al. (2015) developed an integrative model for the study of emerging market multinational enterprises. Their framework proposes three levels for the MNE: (a) the Strategic Context, combining the five internationalization strategies for emerging market MNEs (RAMAMURTI; SINGH, 2009), the country-of-origin effects (ELANGO; SETHI, 2007; SETHI; ELANGO, 1999), and the Global Production Network as discussed in 2.4.1, (b) the MNE as a network of subsidiaries, based on the IIN model from Shi and Gregory (1998) and (c) the subsidiary network, formed by its local operations, characterized according to Ferdows (1997), the Resource-Based View of the firm (BARNEY, 2001; FLEURY; FLEURY, 2007), and host-country effects that are similar to the home-country effects (FLEURY et al. 2015). From the first level of this model, we will use the strategic context level as the basis to develop the DT strategy concept, described later in section 2.7; the model from Shi and Gregory to look at the evolution of configurations of the IIN and the role of plants from Ferdows to analyze the evolution of plants with DT.

Cheng, Farooq, and Johansen (2011) and Feldmann et al. (2013) study how changing a plant's role affects the other plants and the IIN. They combine the plant role model from Ferdows (1997) and the IIN configuration model from Shi and Gregory (1998) and use a longitudinal approach to map the IIN's and plants' evolution. The conclusion is that despite the complexity of IINs, changes in plant roles can provide higher flexibility and more choices to arrange global production and meet the changing requirements of their global markets (CHENG; FAROOQ; JOHANSEN, 2011; FELDMANN et al., 2013). Blomqvist and Turkulainen (2019) reach a similar conclusion, although they use the plant's degree of dependency within the IIN instead of the strategic reason to locate as one of their model's dimensions. Blumqvist and Turkulainen (2019), Cheng, Farooq, and Johansen (2011), and Feldmann et al. (2013) support the two levels of analysis approach we use in the current research.

I3.0 sped firms' internationalization forming complex IINs in the 1990s and early 2000s when researchers like Ferdows, Shi, and Gregory developed their models. Despite the informatization and incipient connectivity of I3.0 systems at the plant level, there were still severe limitations to real-time data flow and analysis at the IIN level that would have to wait for further technological developments to become a reality.

2.5 DIGITAL TRANSFORMATION (DT)

2.5.1 Origins and base for the literature review on DT

At the Hannover Messe in Germany back in 2011, the German Government, Academy, and Industry coined the term “Industrie 4.0” (KAGERMANN; WAHLSTER; HELBIG, 2013), also known as industry 4.0 (I4.0). A few years later, Klaus Schwab from the World Economic Forum presented the term “fourth industrial revolution” (SCHWAB, 2017). Authors use these two terms and “digital transformation” interchangeably or as closely intertwined (ANDERL, 2016; FRANK, DALENOGARE, AYALA, 2019) to describe the phenomenon of popularization of the internet and the constant capacity increase of data generation, processing, transmitting, storing, and analysis ever since. Together with recent technological, social, and political developments in the world, this incipient field of research has originated a considerable body of literature, counting with several excellent literature reviews (ALCÁCER; CRUZ-MACHADO, 2019; LIAO et al., 2017, 2018; RODRIGUES et al., 2016; XU; XU; LI, 2018). In the following section, we present a summary of technology evolution across the industrial revolutions to understand their essential characteristics and the differentials of the fourth industrial revolution to the previous ones. We demonstrate why the literature considers the terms “fourth industrial revolution” and I4.0 as synonyms. In Section 2.5.3, we present the difficulties of finding a useful definition of I4.0. In Section 2.5.4, we explain the differences between I4.0 and DT, justify using the latter to build our conceptual framework, and provide a working definition of DT as an evolutionary process.

2.5.2 The Fourth Industrial Revolution

The fourth industrial revolution denotes recent developments that are changing the world’s face as we know it in the same way previous industrial revolutions did in the past (FRANK; DALENOGARE; AYALA, 2019; SCHWAB, 2017). The first industrial revolution took place by the end of the 18th century with the invention of the steam machine that moved the industry from the home to the factory environment, the creation of railroads, and the replacement of sailboats with steamboats (BARBOSA; BAISSO; ALMEIDA, 2018; DRATH; HORCH, 2014). By the end of the 19th century, the second industrial revolution, or Industry 2.0, introduced the electrification, the oil industry, the birth of the production line, and marked the birth of OM with Frederick

Winslow Taylor's "Principles of Scientific Management" in 1911 (TAYLOR, 1998). Taylor developed a methodology for the work division study that Henry Ford introduced in his production line, represented by the Ford Model-T manufactured in the River Rouge plant, widely adopted by the industry (WILSON, 2014). After World War II, Taiichi Ohno developed the Toyota Production System, an evolution of Henry Ford's production line (YIN; STECKE; LI, 2018). Ford's and Toyota's systems still find wide application in the industry and other non-industrial sectors (BARBOSA; BAISO; ALMEIDA, 2018; YIN; STECKE; LI, 2018).

The third industrial revolution, also known as I3.0, or digital revolution (SCHWAB, 2017), starts in the 1950s with the first programmable logic controllers, evolves with the introduction of industrial automation and electronic systems that significantly improved productivity and the dissemination of the Toyota production system outside of Japan as the Lean Manufacturing (DALENOGARE et al., 2018; KRAFCIK, 1998; YIN; STECKE; LI,2018). Industrial robots, computer systems, and early internet tools characterize the third industrial revolution (LIAO et al., 2018; RODRIGUES; DE JESUS; SCHÜTZER, 2016; SCHWAB, 2017).

The fourth industrial revolution is currently under development with uncertain outcomes (DRATH; HORCH, 2014). Its distinction from the previous revolutions is applying digital technologies that melt the physical, digital, and biological worlds (SCHWAB, 2017). Low-cost sensors, interactive robots, additive manufacturing, and nanomaterials represent the physical world. In contrast, the internet of things (IoT), the internet of services (IoS), cloud computing (CC), big data analytics (BDA), blockchain, artificial intelligence (AI), and digital platforms represent the digital world, while telemedicine, genetic engineering, and robotized medicine depict the biological world (BARBOSA; BAISO; ALMEIDA, 2018; SCHWAB, 2017). Schwab (2017) identifies three factors of differentiation: a) the speed of development and interconnection of the enabling technologies; b) the breadth and depth of the changes to the economy, business, and people's daily life; and c) the transformations that those technologies cause to countries, societies, firms, and organizations (BARBOSA; BAISO; ALMEIDA, 2018; SCHWAB, 2017). Like the three previous industrial revolutions, the fourth industrial revolution brings a technological and an organizational breakthrough (YIN; STECKE; LI, 2018).

Schwab (2017) describes the fourth industrial revolution as integrating the physical, digital, and biological worlds in different levels of the entire society, a broader scope than his understanding of the I4.0 that focuses on manufacturing and does not encompass the biological integration of worlds (BARBOSA; BAISO; ALMEIDA, 2018; DRATH; HORCH, 2014; LICHTBLAU et al., 2015; SCHWAB, 2017). Nevertheless, several authors use the terms “fourth industrial revolution” and “industry 4.0” as synonyms (DRATH; HORCH, 2014; LASI et al., 2014; LICHTBLAU et al., 2015; OZTEMEL; GURSEV, 2018; RODRIGUES; DE JESUS; SCHÜTZER, 2016; VAIDYA; AMBAD; BHOSLE, 2018; WANG et al., 2016). I4.0 integrates not just the production but the entire life cycle of products and services that involve all functions of the firm, its supply network, and its clients (FRANK; DALENOGARE; AYALA, 2019). We use the fourth industrial revolution and I4.0 as synonyms for the remainder of this text. Since the former lacks a formal definition, we now turn our attention to I4.0.

2.5.3 Industry 4.0 (I4.0)

When industry, academy, and government representatives sat together to discuss emerging technologies and the future of the German industry at the German Hannover Fair in 2011, they came out with the term “Industrie 4.0” for the first time (ALCÁCER; CRUZ-MACHADO, 2019; TORTORELLA; FETTERMANN, 2018; XU; XU; LI, 2018). The working group, commissioned to prepare recommendations, issued a final report entitled “Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Securing the future of German manufacturing industry; final report of the Industrie 4.0 Working Group” that envisions a combination of the physical and digital domains based on the internet as a vehicle for data transmission for products (IoT) and services (IoS). (KAGERMANN; WAHLSER; HELBIG,2013).

While in I3.0, the integration of systems was slow with manual data handling and a hierarchical structure, in I4.0, systems communicate in real-time using automated data handling, cloud repositories, and a network structure, described as Reference Architecture Model I4.0 – RAMI4.0 by the norms IEC 62264 and 61512 (ADOLPHS et al., 2015; KOLBERG; KNOBLOCH; ZÜHLKE, 2017). Several technologies combine to enable I4.0, like cheap sensors to collect data, the IoT and IoS to transmit it, CC to store a large amount of data, BDA, and AI that enable automated simulation, forecast, and decision making (ALCÁCER & CRUZ-MACHADO, 2019). Together, they allow firms to build digital shadows or twins representing the physical systems, connecting the physical and digital worlds. Digital and physical counterparts instantly update each other, forming a Cyber-Physical System (CPS) (KAGERMANN, WAHLSER, HELBIG, 2013; SCHWAB, 2017; STRANGE E ZUCCHELLA, 2017). Digital technologies interconnect operations' systems in real-time. CPSs and digital platforms integrate different functions like R&D, production, supply chain, sales, and after-sales, reshaping business models, products, and service offerings (ALCÁCER; CRUZ-MACHADO, 2019).

Many attempts to conceptualize I4.0 rely on extensive literature reviews (CULOT et al., 2020; HERMANN; PENTEK; OTTO, 2016; OZTEMEL; GURSEV, 2018). Table 4 presents different definitions in the academic literature and a short list of texts that either reference or imply a similar definition. The definition from Hermann, Pentek, and Otto (2016) extends I4.0 to the entire value network of the firm using the concepts of CPS, IoT, and IoS. Lichtblau et al. (2015) extend the definition to the product life cycle, including those agents contributing to creating and capturing value for the firm.

Culot et al. (2020) identify three commonalities among the definitions of I4.0: a) key enabling technologies for digitalization and integration, b) distinctive characteristics like real-time information sharing, autonomy, and process integration within and across firms, and c) outcomes portrayed as higher productivity, flexibility, and mass customization capability. Many of the articles on I4.0 focus on enabling technologies. For example, Hermann, Pentek, and Otto (2015), and Frank, Dalenogare, and Ayala (2019) identify the CPS as the backbone technological element for I4.0 that deliver distinctive characteristics of interoperability, virtualization, decentralization, real-time capability, service orientation, and modularity, covering the three commonalities pointed by Culot et al. (2020). Kumar, Mookerjee, and Shubham (2018) present digital platforms as an essential and under-researched tool for integration in real-time operating systems, functions, and business partners.

Table 4 – I4.0 definitions in the literature

AUTHORS	DEFINITION	Articles that use a similar definition
Hermann, Pentek, Otto (2016, p.11)	“Industrie 4.0 is a collective term for technologies and concepts of value chain organization. Within the modular structured Smart Factories of Industrie 4.0, CPSs monitor physical processes, create a virtual copy of the physical world, and make decentralized decisions. Over the IoT, CPSs communicate and cooperate with each other and humans in real-time. Via the IoS, both internal and cross-organizational services are offered and utilized by participants of the value chain.”	Alcácer and Cruz-Machado (2019); Dalenogare et al. (2018); Liao et al. (2017); Lu (2018); Tortorella and Fettermann (2018); Xu, Xu, and Li (2018)
Adolphs et al. (2015, p. 5)	“One of the fundamental ideas on the reference architecture of Industrie 4.0 is the grouping of highly diverse aspects in a common model. Vertical integration within the factory describes the networking of means of production, e. g. automation devices or services. As a new aspect in Industrie 4.0, the product or workpiece is also involved. The corresponding model must reflect this aspect. But Industrie 4.0 goes considerably further. End-to-end engineering throughout the value stream means that the technical, administrative, and commercial data created in the ambit of a means of production or the workpiece are kept consistent within the entire value stream and can be accessed via the network at all times. The third aspect in Industrie 4.0 is horizontal integration via added-value networks, extending beyond individual factory locations, and facilitating the dynamic creation of such added value networks.”	Alcácer and Cruz-Machado (2019); Anderl (2016); Rodrigues, De Jesus and Schützer (2016); Sony, 2018; Kolberg, Knobloch, and Zühlke (2017)
Lichtblau et al. (2015, p. 11)	“The term Industrie 4.0 stands for the fourth industrial revolution, a new level of organizing and controlling the entire value chain across product lifecycles. This cycle focuses on increasingly personalized customer wishes and extends from the concept to the order, development, production, and shipping of a product to the end customer and ultimately to its recycling, including all associated services.”	Vaidya, Ambad, and Bhosle (2018) Tjahjono et al. (2017)
Schumacher, Erol, and Sihn (2016, p.162)	“Industry 4.0 refers to recent technological advances where the internet and supporting technologies (e.g., embedded systems) serve as a backbone to integrate physical objects, human actors, intelligent machines, production lines and processes across organizational boundaries to form a new kind of intelligent, networked and agile value chain.”	Moeuf et al. (2018), Vaidya, Ambad, and Bhosle (2018)
Buer, Strandhagen, and Chan (2018, p.2925)	“Industry 4.0 is operationalized as the usage of intelligent products and processes, which enables autonomous data collection and analysis as well as the interaction between products, processes, suppliers, and customers through the internet.”	
Oztemel and Gursev (2018, p.166)	“Industry 4.0 is a manufacturing philosophy that includes modern automation systems with a cretin level autonomy, flexible and effective data exchanges encoring the implementation of next-generation production technologies, innovation in design, and more personal and more agile in production as well as customized products.”	

Source: Compiled by the author

The discussion above suggests that defining I4.0 is challenging due to its complexity. That implies a difficulty in operationalizing the construct. Culot et al. (2020) consider the maturity models (LICHTBLAU et al., 2015; SCHUMACHER; EROL; SIHN, 2016; SCHUH et al., 2017, 2020a) as an initial operationalization attempt. However, Culot et al. (2020) caution about their use because a) they assume that there is a linear and optimal implementation process instead of an evolutionary process that may face linear as well as disruptive changes, b) they do not consider the fact that I4.0 may be subject to a path related to contextual factors. Despite their limitations, digital maturity models may provide a framework to evaluate a firm's advancement before and after they undergo an I4.0 implementation process. We will return to digital maturity models later in section 2.6. For now, we turn our attention to DT, the third term commonly used as a synonym to the fourth industrial revolution and I4.0.

2.5.4 Digital transformation

If not a synonym, Digital transformation (DT) finds use as the process to implement the I4.0 program (FRANK; DALENOGARE; AYALA, 2019; FRANK et al., 2019; GHOBAKHLOO; 2018; XU; XU; LI, 2018; YIN; STECKE; LI, 2018). There are few attempts to define DT in OM. Culot et al. (2020) underline the key enabling digital technologies and the strategic aspect of DT in their attempt to build a concept for I4.0. When discussing the impact of digital technologies in the servitization of firms, Frank et al. (2019, p. 343) define DT "*as the transition process companies are facing when moving from previous industrial stages to an interconnected smart enterprise of the Industry 4.0 era supported by these base technologies*". This definition suggests that DT is a process to take a firm from an initial stage to a final stage by implementing digital technologies. This section expands the literature review on DT to other fields of knowledge like Information Systems, Innovation, and Management, searching for a formal definition for the term. We present other authors who have already taken this task and use their contributions to build our DT working definition.

Rooted in the Business area but adopting a multi-functional approach that is in line with the expectations of functions integration from I4.0, Verhoef et al. (2019, p. 1) review the literature on strategy, innovation, information systems, OM, and marketing, to define DT as *"a change in how a firm employs digital technologies, to develop a new digital business model that helps to create and appropriate more value for the firm."*

Verhoef et al. (2019) limit their definition to creating a new business model to argue that DT is a three-phased process and supports the need for a DT strategy that involves both technological and organizational dimensions with expected outcomes. Regarding the DT process, Veroef et al. (2019) identify three phases: (a) digitation that transforms analog information into digital data that can be stored, processed, and transmitted; (b) digitalization, where business processes incorporate digital technologies; (c) DT that develops new business models. This definition assumes a need to set a sequence to the phases so that digitation comes before digitalization, preceding DT.

Schallmo, Williams, and Boardman (2017, p. 1740014-4) list a series of definitions from the academy, consulting firms, and the German government to define DT as: "*the networking of actors such as businesses and customers across all value-added chain segments, and the application of new technologies… involving companies, business models, processes, relationships, products, etc.*" Schallmo, Williams, and Boardman (2017) describe the new technologies in line with the discussion presented in section 2.4.3 and consider digitization, digitalization, and DT interchangeable terms, contrary to Veroef et al. (2019). Another definition that highlights business models appears in Nasiri et al. (2020, p. 2): "*the transformation of business process, culture, and organizational aspects to meet market requirements, owing to digital technologies*." This definition focuses on DT's organizational dimension and suggests that there should be a market push for its implementation.

Information Systems is an area where several authors make efforts to define DT. Roedder et al. (2016) define digitation like Veroef et al. (2019) but argue that digitalization and DT find interchangeable use in the literature so that the implementation of digital technologies may generate new business models, services and improve productivity. They list digital technologies as those presented in section 2.4.3. Singh, Klarner, and Hess (2020) define DT as a game-changing tool for the company that requires a strategic approach to deliver a change in the scope of the business, operations, products, and even business models.

Based on a semantics analysis of twenty-three extant definitions from the Information System field using the rules for conceptual definitions from Wacker (2004) and the guidelines for conceptual clarity from Suddaby (2010), Vial (2019, p. 118) defines DT as "*a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies*." Vial (2019) claims that his definition (a) aligns with the related definition of "digitalization" that encompass individual, organizational, and societal contexts, (b) expects improvement as an expected outcome, and (c) avoids the use of the term "digital technologies" that has no clear definition.

DT is a "process," according to Frank et al. (2019) and Vial (2019). Other definitions propose terms that are difficult to operationalize, such as "change" (Veroef et al.), "networking" (SHALLMO et al., 2017), "transformation" (NASIRI et al., 2020), and "game-changing tool" (SINGH; KLARNER; HESS, 2020). The process takes place at an entity. Most authors apply their definitions to the "firm" or "company," although Vial (2019) prefers the term "entity," arguing that it is more general and permits the application of his definition to societies and governments. Since we are studying MNEs, our definition should include these specific entities (MNEs).

Regarding the strategic approach to implementing the DT, Vial (2019) provides the most general description, "trigger significant changes to properties." Nasiri et al. (2020) and Singh, Klarner, and Hess (2020) tend to generality by describing changes to the firm such as "products, processes, operations, culture, organizational aspects, and business models," while Frank et al. (2019) use a "change supported by base technologies" without detailing any specific strategic approach. Veroef et al. (2019) and Shallmo et al. (2017) limit their definition to the business model. While this is a valuable strategy, it is not all-inclusive. We opt to maintain the general approach from Vial (2019) but will consider Nasiri et al. (2020) and Singh, Klarner, and Hess (2020) in our discussions about DT strategies.

Looking at the process inputs and outputs, Vial (2019) does not propose a specific initial nor final stage for DT. Firms are currently starting or in process, so we believe this generality favors our study because we can observe DT improvements without specific concerns on evolutionary stages or targeted results. The lack of an ending point will be significant for evaluating the DT progress using the two dimensions of technology and organization that we address under section 2.6. Table 5 compares the definitions presented and sets the frame to propose our definition for this work.

Table 5 - Extant definitions for DT

Authors	Type	Unit of analysis	Strategic approach	Initial condition	Final condition	Transf. tool(s)
Frank et al. (2019)	process	firm	Change	Previous industrial stage	Interconnected smart enterprise of the I4.0 era	Base technologies
Veroef et al. (2019)	Change (process?)	firm	New business model	Create an appropriate value		Digital technologies
Shallmo et al. (2017)	Networking	Value-added chain	New business model	Changes in products, processes, relationships, etc.		Digital technologies
Nasiri et al. (2020)	Transformation		Changes in business process, culture, organization		Meet market requirements	Digital technologies
Singh, Klarner, and Hess (2020)	Game-changing tool	firm	Change in the scope of business, operations, products, and even business models			
Vial (2019)	process	entity	Trigger significant changes to properties	Improve the entity		Combinations of information, computing, communication, and connectivity technologies

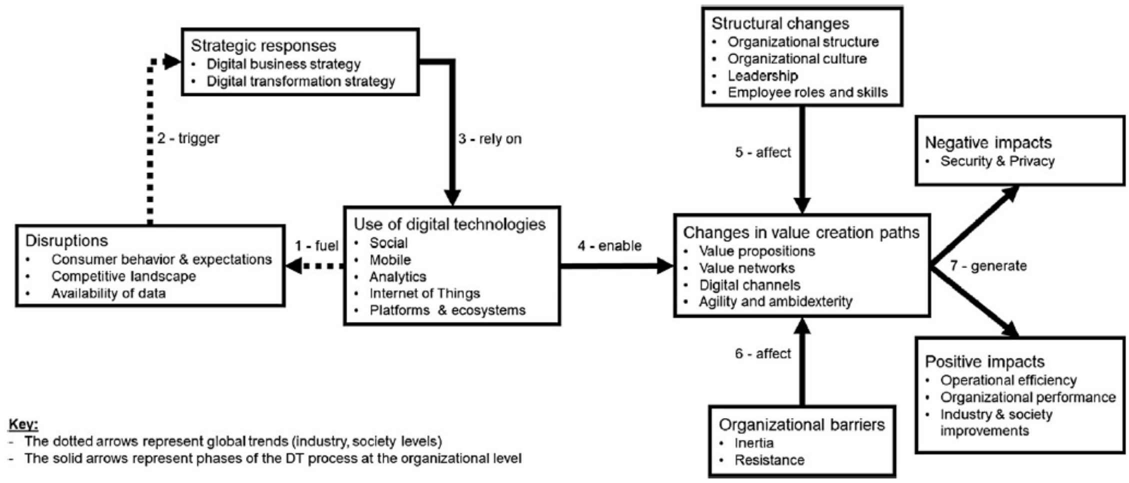
Source: author

Our final observation to elaborate our definition of DT is on the required tools. Most authors use “digital technologies” in their definitions. Vial (2019) tries to avoid the term by using “*combinations of information, computing, communication, and connectivity technologies*,” but returns to “*digital technologies*” in the remainder of his text, including in his framework depicted in Figure 2 and discussed in the paragraphs that follow. Considering the discussion from the previous paragraphs, we use our research question to propose the following DT definition for this work:

> “*Digital transformation is a process that aims to improve the MNE by triggering significant changes to its IIN configuration and plant roles through combinations of digital technologies*.”

Given that the definition describes an evolutionary process, we can now observe the MNE’s evolution through changes in the IIN’s configuration and its plants' roles. The framework from Vial (2019), depicted in Figure 2, is a good starting point for that purpose.

Figure 2 – Digital transformation framework



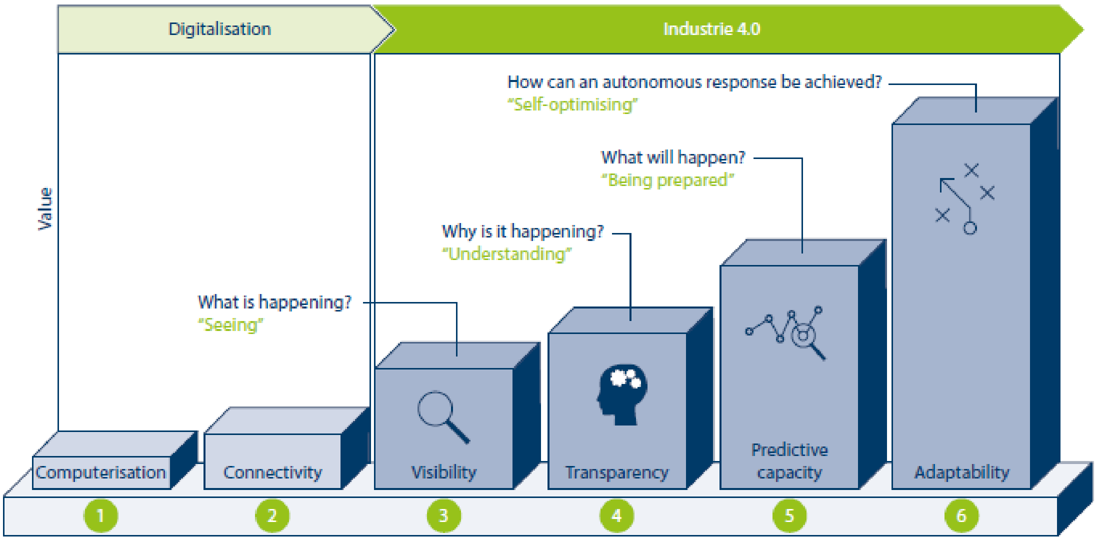
Source: Vial, 2019

Vial's framework consists of the following building blocks: *new digital technologies* create *disruptions* at the society and industry levels, triggering *strategic responses* by the firms aiming to adopt these technologies to *change their value creation paths*; DT will require *structural* changes, may face *organizational barriers*, and generate both *positive intended* and *unintended negative outputs*. In the firm context, Vial (2019) lists I4.0 technologies and digital platforms as "digital technologies," recognizes the need to adjust both the technological and the organizational structures to implement the new technologies expecting improvement outcomes from the process. Comparing DT with IT-transformation, Vial (2019) underscores that the former combines digital technologies and transforms business processes, reaching the firm and its innovation and business ecosystems, while the latter has an internal scope, typically limited to the organization it serves. The following section describes how literature treats the issue of measuring the evolution of DT.

2.6 THE DIMENSIONS OF DT

The DT process requires changes in both the technological and organizational dimensions (SCHAGERL; JODLBAUER; BRUNNER, 2016; FRANK; DALENOGARE; AYALA, 2019; LANZA; HAEFNER; KRAEMER, 2015; LICHTBLAU et al., 2015; SCHUH et al., 2017, 2020a, b; SCHUMACHER; EROL; SIHN, 2016). These two dimensions recognize that technological transformations alone are insufficient to promote DT. The technological and organizational dimensions are the base of the attempts to track DT's advancement in firms using maturity models. However, they present several limitations due to assumptions like an optimal linear implementation path, an ideal final stage, and a linear evolution path (CULOT et al., 2020).

Figure 3 - Stages in DT



Source: Schuh et al. (2017, 2020)

The German Acatech "Industrie 4.0 maturity index" (SCHUH et al., 2017, 2020a) presents six stages related to different technical capabilities, the first two representing the digitalization or I3.0, a) computerization, and b) connectivity, while the next four stages represent industry 4.0 capabilities c) visibility, d) transparency, e) prediction and f) adaptability. The I3.0 stages represent the preparation that will enable the industry 4.0 stages to build the CPSs. The CPS is a digital shadow in the visibility stage, becomes a digital twin in the transparency stage, makes accurate simulations in the prediction stage, and makes decisions automatically in the adaptability stage. Figure 3 represents the several stages in the Acatech. Although progress in the model requires new organizational and technological advances, only the technological dimension labels each stage.

After comparing several models to evaluate digital transformation, Schumacher, Erol, and Sihn (2016) conclude that the Acatech model provides a better theoretical base. For this reason, several authors build their proposals using the Acatech model

(FLEURY et al., 2019; FRANK; DALENOGARE; AYALA, 2019; KERMER-MEYER, 2017; SCHUMACHER; EROL; SIHN, 2016; SINGAPORE, 2018). Table 6 compares some digital maturity models, highlighting the two main dimensions of technology and organization.

Table 6 – Literature indicators for digital maturity

DIMENSION	Acatech (Schuh et al., 2017, 2020a)	PWC (2019)	Schumacher, Erol, and Sihn (2016)	IMPULS Lichtblau et al. (2015)	Frank et al. (2019)	Kermer-Meyer (2017)
TECHNOLOGY	Resources Information Systems	Degree of digitalization for: Business models, products, and services Access to clients and markets Value Chains IT Architecture Compliance	Digital technologies Customers integration Products integration Operations integration	Smart factory Smart operations Smart products Data-driven services	FRONT END Smart Manufacture Smart products Smart work processes Smart Supply Chain Cloud, IoT, BD, Analytics	Smart Solutions Smart innovation Smart networks Smart Production Information Technologies Resources
ORGANIZATION	Organizational structure . Culture	Organization and culture	Digital Strategy Leadership Culture People Governance	Digital Strategy and organization Employees	NOT COVERED	Business models Digital strategy and vision Culture and Mindset

Source: author

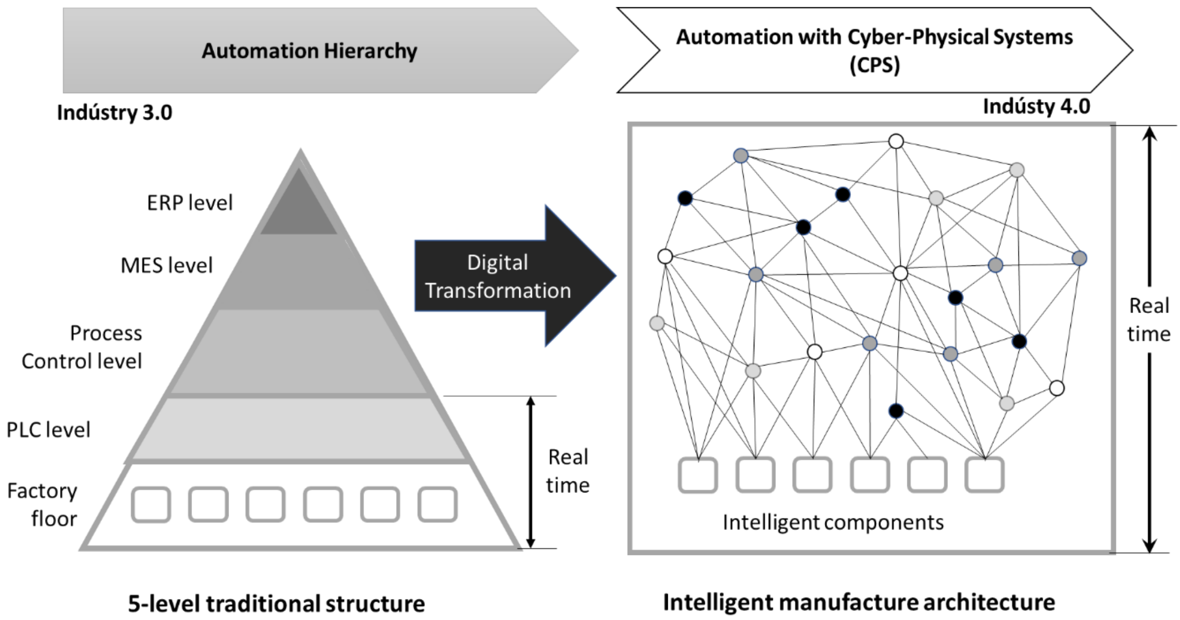
The main advantage of the Acatech model is that it measures four structural areas across the firm's manufacturing functions. The two structural areas to assess the technological dimension are a) resources and b) information systems, and the two related to the organizational dimension are c) organizational structure and d) culture. The functional areas evaluated characterize traditional manufacturing, such as a) development, b) production, c) logistics, d) services, and e) marketing & sales (SCHUH et al., 2017, 2020a). Schuh et al. (2017, 2020a) present a clear description of their structural areas but omit operationalization details. It is not clear if they consider issues like inter-functional integration or the use of digital platforms, suggested by characteristics like “customer integration” (SCHUMACHER; EROL; SIHN, 2016), “data-driven services” (LICHTBLAU et al., 2017), “smart supply chain” (FRANK; DALENOGARE; AYALA, 2019), “smart networks,” and “smart innovation” (KERMER-MEYER, 2017). Another element in Table 6 but not in the Acatech model is the Digital Strategy that we will cover separately in section 2.7. We describe the technological and organizational dimensions using the literature on DT and articles about maturity models in the next paragraphs.

2.6.1 The technological dimension

RAMI4.0 represents DT's technological dimension by promoting vertical, horizontal, and product life-cycle integration (ADOLPHS et al., 2015; ALCÁCER; CRUZ-MACHADO, 2019; KOLBERG; KNOBLOCH; ZÜHLKE, 2017; RODRIGUES, DE JESUS; SCHÜTZER, 2016; SONY, 2018). The vertical integration involves parts, products, machines on the floor, process control systems, manufacturing execution systems, and enterprise resource programming at the plant, subsidiary, and MNE levels, providing internal IIN integration (ADOLPHS et al., 2015). The horizontal integration encompasses the entire supply chain, including internal functions like procurement and materials supply, plants, distribution centers, sales, marketing, and administrative functions, and external partners like the supply chain and customers; the life-cycle integration occurs across the entire life of the product, from R&D, production, distribution, sales, use, and product recycling or disposal (ADOLPHS et al., 2015). CPSs are the technological backbone of the three types of integrations from RAMI40. CPSs, people, and different organizations collaborate through digital platforms. (ALCÁCER; CRUZ-MACHADO, 2019; CULOT et al., 2020; FRANK; DALENOGARE; AYALA, 2019; GAWER, 2014; GHOBAKHLOO, 2018; MOEUF et al., 2018; OZTEMEL; GURSEV, 2018; VIAL, 2019). Therefore, the CPSs and digital platforms materialize RAMI4.0.

The CPS is a tool to unite the physical and digital domains through computer networks that monitor the physical processes and involve control loops where physical systems control digital systems and vice-versa (HERMANN; PENTEK; OTTO, 2016; LEE; BAGHERI; KAO, 2015; LU, 2017; MONOSTORI et al., 2016; RODRIGUES; DE JESUS; SCHÜTZER, 2016). Each physical object from the system has a digital representation, and each component from the cybernetical system has a physical counterpart. The link between physical and digital allied to robust and intelligent software enables the collaboration, adaptation, and evolution of the CPS (COLOMBO et al., 2017). Several complex digital technologies combine to form the CPS. Sensors capture and digitize the physical world conditions, the IoT and IoS to instantly update a cloud repository that stores vast amounts of data, the capability to analyze the data with BDA, the use of AI to simulate, forecast, take automated decisions, or interact with humans, updating the digital and physical parts in real-time (ALCÁCER; CRUZ-MACHADO; 2019; LEE; BAGHERI; KAO, 2014; MOEUF et al., 2018; NEGRI; FUMAGALLI; MACCHI, 2017; OZTEMEL GURSEV, 2018).

Figure 4 – Hierarchical (I3.0) x network architecture (I4.0)



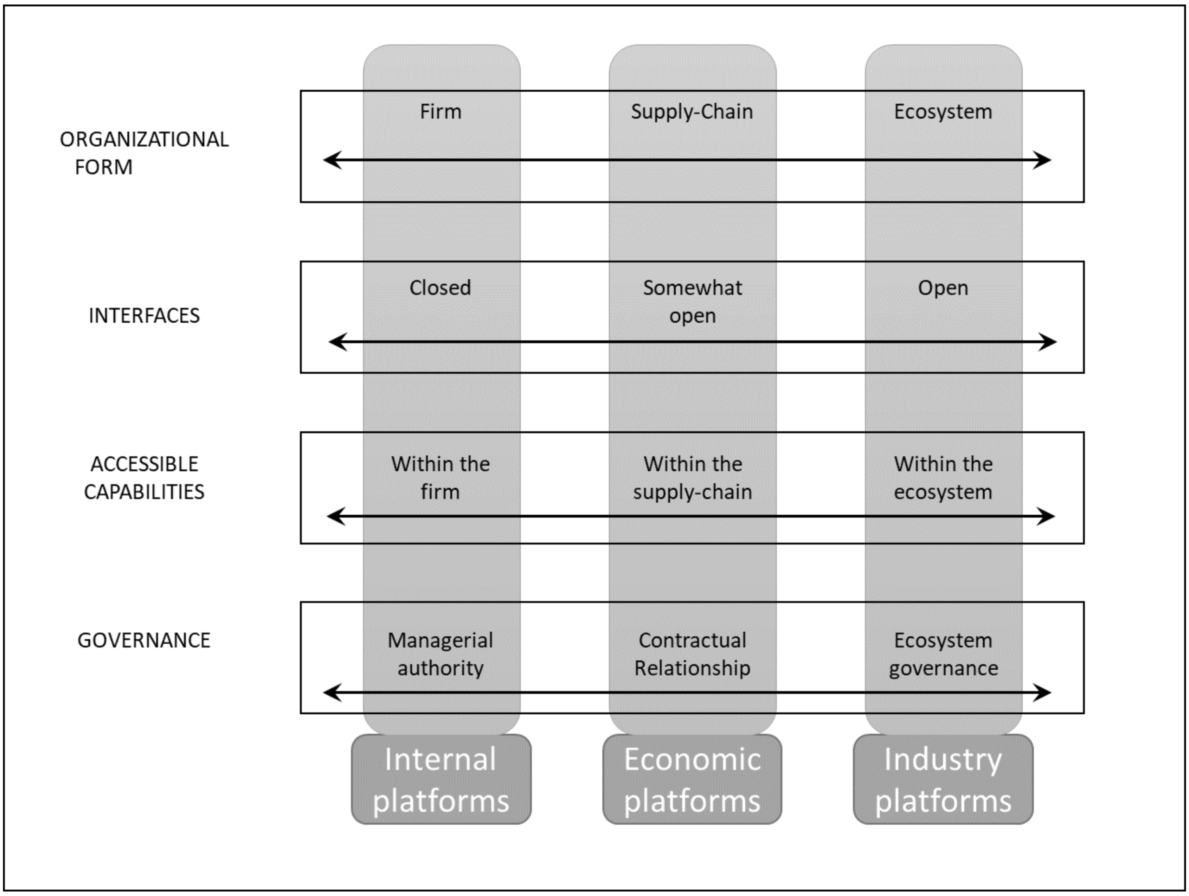
Source: Adapted from Monostori et al. (2016)

According to its capability, the digital part of a CPS is a digital “model,” “shadow,” or “twin.” The digital model is a separate representation of a physical system without any interaction capability. The digital shadow is a digital model with constant data flow from the physical part to the digital part of the CPS, but no data flow in the other direction; the digital twin has the capability of data flow in both ways so that the physical system updates the digital part, and any change to the digital part reflects in the physical system (KRITZINGER et al., 2018; SCHROEDER et al., 2016). The critical difference between the I3.0 digital systems and the I4.0 CPS is the system architecture. While I3.0 operates in a hierarchical architecture that only allows a system to communicate to the next level in almost real-time, generating delays when considering several layers of systems, I4.0 makes use of the cloud repository for instant update of data for all connected systems in network architecture, as shown in Figure 4 (MONOSTORI ET AL., 2016).

Digital platforms enable the inclusion of the highest possible number of participants in an environment or ecosystem (GAWER, 2014; GAWER; CUSUMANO, 2014). Some digital platforms intend to create value in an innovation ecosystem, while others capture value in a business ecosystem (DE VASCONCELOS GOMES et al., 2018). Gawer (2014) proposes three types of digital platforms depending on their use: a) Internal platforms are used within the firm to meet the needs of people and systems at different levels, plants, and functions inside the IIN of the firm; b) economic or supply chain platforms that support the business ecosystem formed by suppliers, customers, clients, and end-users; and c) industrial platforms, used to build innovation ecosystems, intended for research and development of products, services, systems and applications, open to any contributor like research institutes, universities, complementors, users and supply chain partners. Digital platforms allow faster and broader community involvement for value creation and capture (GAWER, 2014; DE VASCONCELOS GOMES et al., 2018). Figure 5 illustrates Gawer's typology.

According to Gawer (2014), the internal platform belongs to the firm to serve the IIN in different systems, levels, functions, and operations, possesses a closed interface, controlled, and limited to the IIN through management governance, therefore limiting knowledge, competencies, and data sharing to within the firm. The relationships among the business ecosystem participants rule the digital economic platform's governance, restricting interfaces, knowledge, capabilities, and data sharing to that platform and its participants (GAWER, 2014). The innovation ecosystem determines the industry ecosystem's governance, aggregating competencies to develop new products, services, processes, and systems. The ecosystem is open to all participants interested in contributing to the platform, like research institutes, universities, complementors, users, partners, or any other party (GAWER, 2014).

Figure 5 - Internal, economic, and industrial platforms



Source: Gawer, 2014

Internal platforms support the IIN to optimize its coordination as "an intra-firm network of plants located in different places" (CHENG; FAROOQ; JOHANSEN, 2015, p.393). Economic platforms enable plants to engage with their partners and the supply chain to improve value capture in their business ecosystem, while industrial platforms promote faster, dynamic, and diversified innovation ecosystems (DE VASCONCELOS GOMES et al., 2018; GAWER, 2014). We use the typology from Gawer (2014) to analyze three different interactions: a) those internal to the IIN through internal platforms, b) those happening between the IIN and Recentementeits business ecosystem through economic platforms, and c) those between the IIN and its innovation ecosystem through industrial platforms. The next paragraph provides an overview of ecosystems.

Moore (1993) coined the concept of the business ecosystem, while Adner (2006) expanded it by suggesting that the business ecosystem was also an innovation ecosystem (DE VASCONCELOS GOMES et al., 2018). De Vasconcelos Gomes et al.

(2018) review the literature to summarize five universal features of ecosystems: a) an interconnected and interdependent network of actors, b) the existence of a digital platform, c) the coordination by a platform leader or keystone actor, d) the occurrence of simultaneous cooperation and competition, and e) the existence of a life cycle with a co-evolutionary process.

Adner (2006), Adner and Kapoor (2010), Gawer and Cusumano (2014), and Nambisan and Baron (2013) use the terms business ecosystem and innovation ecosystem as synonyms. Others like de Vasconcelos Gomes et al. (2018), Tsujimoto et al. (2018), and Valkokari (2015) differentiate the two terms arguing that the innovation ecosystem deals with value creation, while the business ecosystem promotes value capture, based on the differentiation of industrial and economic platforms from Gawer (2014), and the statement from Adner and Kapoor (2010) that value creation precedes value capture. De Vasconcelos Gomes et al. (2018) argue that the constructs “innovation ecosystem” and “business ecosystem” open new possibilities to operationalize the environment, including policymakers, customers, and other complementary actors, while the traditional constructs of chains and networks only include those actors directly involved in the production or service flows. In this work, we adopt the perspective of De Vasconcelos et al. (2018), Tsujimoto et al. (2018), and Valkokari (2015). We also consider that the IIN is an internal ecosystem as it complies with the five features of an ecosystem described in the previous paragraph. After concluding the review of the technological dimension of I4.0, we proceed to review the organizational dimension.

Recently, OM researchers have paid more attention to ecosystems to study the complex relationships involving the development and use of digital technologies. For example, Kapoor et al. (2021) discuss the implications of using digital platforms and ecosystems in firms' servitization. Benitez, Ayala, and Frank (2020) shed light on the role of innovation ecosystems in creating digital solutions. Hou and Shi (2020) propose an integrative framework for ecosystems using the structure and coevolution views. In common, these papers suggest that ecosystems provide better explanatory power to the mechanisms that promote innovation and business than the traditional dyadic relationships of supply or value chains (BENITEZ; AYALA; FRANK, 2020; HOU; SHI, 2020; KAPOOR et al., 2021).

2.6.2 The organizational dimension

The second dimension of I4.0 is organizational transformation. To cope with new technologies, CPS, and digital platforms, firms must integrate them into existing systems (TORTORELLA; FETTERMANN, 2017). When discussing the industrial revolutions, we pointed out that the main organizational change brought by the third industrial revolution or I3.0 was the broad implementation of lean manufacturing. The lean and DT interfaces are a significant concern for the papers that address organization changes (BUER; STRANDHAGEN; CHAN, 2018; KOLBERG; KNOBLOCH; ZÜHLKE, 2017; MAYR et al.; 2018; MOEUF et al., 2018; TORTORELLA; FETTERMANN, 2018). Some authors argue that the lean and DT approaches are complementary and could develop in sequence or parallel (TORTORELLA; FETTERMANN, 2018). Others suggest that lean precedes DT's implementation, so that lean optimizes processes before their automation with DT (BUER; STRANDHAGEN; CHAN, 2018; KOLBERG; KNOBLOCH; ZÜHLKE, 2017). Mayr et al. (2018) review the literature to provide evidence that DT tools can synergize with lean processes, but also consider that DT or lean tools alone provide benefits to a firm, while Buer, Strandhagen, and Chan (2018) review the literature on the lean-I4.0 interface to conclude that there is still little empirical evidence to support one view or another. Schuh et al. (2020b) describe four cases providing some evidence that lean develops before I4.0, together with early digitalization or I3.0.

DT triggers other organizational changes that include the designation of a Chief Digital Officer (CDO) to lead DT (MATT; HESS; BENLIAN, 2015; SINGH; HESS, 2017; SINGH; KLARNER; HESS, 2020), incorporation of new capabilities inside the organization, development of new organizational structures to cope with digital competencies, the development of cross-functional collaboration structures to break functional silos, and the implementation of initiatives to adjust the organizational culture (HESS et al., 2016; MATT; HESS; BENLIAN, 2015; VEROEF ET AL., 2019; VIAL, 2019). Common cultural adaptation themes are implementing non-hierarchical communication, the willingness to change, taking risks, experimenting using small-scale pilots, and digital data-based decision-making (SCHUH et al., 2017, 2020a, 2020b; VIAL, 2019). In the following sections, we discuss Strategies in IOM, DT strategies, and their implementation through the changes in value creation paths or DT journeys.

2.7 STRATEGIES

2.7.1 Strategy in IOM

A central reference in the strategy literature, Porter (1991, p. 96) defines it "*as a way of integrating the activities of the diverse functional departments within a firm, including marketing, production, research and development, procurement, finance, and the like*." Porter (1986) identifies three main strategic approaches: (a) cost-driven that intends to increase the firm's competitiveness based on offering products or services at a lower cost than competition, (b) differentiation focusing on the offering of superior products or services, and (c) market-focused to provide higher competitiveness in a specific market, although some authors claim that the third strategy, market focus, could be implemented by a combination of the other two (HALLGREN; OLHAGER, 2009). In line with Porter's definition, Schmenner (1982, p. 77), a seminal paper in OM, defines the multi-plant strategy as "*the assignment of specific responsibilities to sometimes far-flung plants*" and identifies four different strategies a firm could develop: (a) product, (b) market, (c) process, and (d) general-purpose. In the product strategy, plants are responsible for manufacturing specific products supplied to all clients. In the market strategy, the plant makes a full range of products for a market delimited in a specific geographic area, while in the process strategy, each plant delivers a feedstock, part, component, or subassembly to the next plant until final assembly takes place in specific pants. Finally, the general-purpose strategy is flexible to assume different strategies and assign plants responsibilities in uncertain or changing conditions (SCHMENNER, 1982). Porter and Schmenner propose typologies that share the characteristic of strategies focused on process optimization, product or service differentiation, and market or customer needs.

In IOM, John Miltenburg (2009, p. 6179) defines strategy as "*a plan for moving a company from where it is to where it wants to be*." Miltenburg (2009) grounds the IIN strategy on the two coordination modes proposed by Shi and Gregory (1998), the global coordinated and the multi-domestic manufacturing, where the former intends to respond to the pressures for globalization and the latter supports local responsiveness. Fleury (1999, p. 553) defines manufacturing strategy as "*the decisions and plans affecting resources and policies directly related to sourcing, production, and delivery of tangible products*." Cha (2020, p. 2) defines global strategy as *"the action in which* *a firm seeks to gain a competitive advantage from its global presence through configuring global-scale business models and coordinating internationally dispersed activities*." The definitions from Fleury (1999) and Cha (2020) apply to MNEs, are in line with those from Schmenner (1982) and Porter (1986,1991).

Being a new phenomenon, DT has attracted the attention of MNEs. As we discussed in the introduction to this work, there are immense opportunities and significant risks in implementing DT. Therefore, it is crucial to implement appropriate DT strategies to exploit opportunities while minimizing risks. To do so, we first define DT strategies and then explore their deployment paths as DT journeys.

2.7.2 DT strategies

Bharadwaj et al. (2013) define the digital business strategy as the fusion of the traditional business and IT strategies, an "*organizational strategy formulated and executed by leveraging digital resources to create differential value*" (BHARADWAJ et al., 2013, p.472). Two key drivers to the digital business strategy from Bharadwaj et al. (2013) are digital technologies and organizational shifts. Although rooted in the IS field, this definition is a predecessor to the DT strategy. It recognizes the need for cross-functional, inter-firm, and product life cycle integration using digital resources and digital platforms (BHARADWAJ et al., 2013; HESS et al., 2016). Other characteristics of the digital business strategy are the scale, measured in both physical and digital dimensions, the speed of product launches and decision making, and the extensive use of data to combine products and services, resulting in new forms of value creation and capture (BHARADWAJ et al., 2013). The digital business strategy focuses on a future state, while the DT strategy intends to conduct the firm through the DT process itself (HESS et al., 2016; VIAL, 2019).

DT strategies aim to achieve product-, process-, and business-centric improvement reflected in higher competitivity and better operational performance (MATT; HESS; BENLIAN, 2015; VIAL, 2019). Although from a different standpoint, these three types of strategies match the types proposed by Schmenner (1982) and Porter (1986; 1991). Sony (2018) describes the process-centric strategy as a vertical integration to improve productivity through waste reduction and process streamline using CPS, the business-centric strategy as a horizontal integration to improve value capture focusing on the needs and requirements of the customers, and the product-centric strategy as the integration of the life cycle of the product to ensure faster development of new products and services. Sony's model also suggests that before embarking on a DT, the firms should streamline their processes using lean manufacturing principles.

Four dimensions characterize DT strategies: (a) use of technologies, (b) structural changes, (c) changes in value creation, and (d) financial aspects (HESS et al., 2016; MATT, HESS; BENLIAN, 2015; SINGH; KLARNER; HESS, 2020). These dimensions match the technological and organizational changes that characterize DT (BHARADWAJ et al., 2013; VEROEF ET AL., 2019; VIAL, 2019). Use of technologies refers to the several possible combinations of technologies like social, mobile, analytics, cloud, and IoT (SEBASTIAN et al., 2017), aimed at different strategic goals (FRANK et al., 2019; SESTINO et al., 2020; VEROEF ET AL., 2019), as discussed in Section 2.6.1. We presented the structural changes in Section 2.6.2 on the organizational dimension. Changes in value creation include new offerings related to current or new products and services, new forms to organize the value chains (BHARADWAJ et al., 2013; HESS ET AL., 2016; VIAL, 2019), or creating new business models (VERHOEF et al., in press); financial aspects refer to competition and other pressures that may accelerate DT inside a firm (MATT; HESS; BENLIAN, 2015).

Sebastian et al. (2017, p. 198) define DT strategy as: "*a business strategy, inspired by the capabilities of powerful, readily accessible technologies, intent on delivering unique, integrated business capabilities in ways that are responsive to constantly changing market conditions*." Sebastian et al. (2017) list two types of strategies*:* customer engagement, a business-centric strategy, or digital solutions, a product-oriented strategy that reframes the value proposition by recombining products, services, and data. Sebastian et al. (2017) omit the process-centric DT strategy, although they recognize the need for a fast and agile response to a changing environment when presenting the operational backbone to deliver agility, flexibility, and productivity.

Another definition for the DT strategy is "*a time-based plan that describes where the company is, where it needs to go and how to get there, based on the Industry 4.0 pre-set visions and plans*" (GHOBAKHLOO, 2018). Ghobakhloo (2018) proposes that the DT strategy should consist of a roadmap, including multi-functional strategies like management, manufacturing, supply chain, marketing, IT, and human resources.

Most of the definitions presented so far relate the DT strategy as a specific type of strategy that uses digital technologies to improve competitiveness (BHARADWAJ et al., 2013; SEBASTIAN et al., 2017). Others mention a plan to take the firm from one step to the other, in line with DT's definition as a process (GHOBAKHLOO, 2018; HESS ET AL., 2016; VIAL, 2019). On the other hand, strategy, in IOM, refers to the reconfiguration and coordination plans for a network of dispersed operations (the IIN) to gain competitive advantages (CHA, 2020; FLEURY, 1999; MILTENBURG, 2009; SCHMENNER, 1982) as presented in the previous section. Therefore, we combine the elements of the IOM global strategy from Section 2.7.1 with components of the DT strategy definitions discussed in this section to propose a working definition of DT strategies for MNEs as follows:

> *“Digital transformation strategy is a plan to conduct the firm through the process that aims to improve the MNE’s competitive advantages by implementing combinations of digital technologies, triggering significant changes to its IIN configuration, coordination, and plant roles.”*

DT strategies may be single-focused or combinations of product-, process-, and business-centric types of strategies, involving the technological, structural, value creation, and financial aspects, as discussed in previous paragraphs (BHARADWAJ et al., 2013; HESS ET AL., 2016; MATT, HESS; BENLIAN, 2015; SINGH; KLARNER; HESS, 2020; VEROEF ET AL., 2019; VIAL, 2019). Besides, specific combinations of technologies provide different ways to execute the DT strategies in MNEs. In the next section, we explore IOM and DT's literature to uncover DT strategies and how they materialize through DT journeys.

2.8 IMPLEMENTING DT STRATEGIES - DT JOURNEYS

Sections 2.3 and 2.4 on IOM and 2.5 to 2.6 on DT explored these two well-researched subjects in OM. Section 2.7 on strategies provided an attempt to bridge those two different perspectives, although IOM strategies focus on the MNE's internationalization, while DT strategies center on incorporating digital technologies into the MNE’s processes. The literature that approaches IOM and DT simultaneously is scarce and underexplored, as mentioned in this work’s introduction. Our exploratory database searches identified over 3,000 articles related to IOM and IINs, and 5,000 articles on DT and I4.0 in our last search in February 2021. Combining the two separate searches provides thirty-five results. Only ten are relevant to our study. The low number of texts is surprising since Kagermann, Wahlster, and Helbig (2013) envisioned an integrated network of plants in their seminal work that coined the term “Industrie 4.0”. We use the ten articles to build our understanding of how the implementation of DT strategies may affect MNEs. The first two, Strange & Zucchella (2017), and Brennan et al. (2015), are editorials that speculate about the impacts of DT on IOM, calling for more research on the subject. Telukdarie et al. (2018) simulate the introduction of an intelligent integrated maintenance system in an IIN to demonstrate its superiority against the traditional isolated systems. Seino (2019) describes how centralized control centers using a commercial digital platform manage services for several MNEs across the world. Garay-Rondero et al. (2019) build a digital supply-chain model that we can replicate at the IIN level. Hannibal (2020) explores the use of additive manufacturing to reshape IINs and their plants. Rooted in a Global Value Chain perspective, Culot, Orzes, and Sartor (2019) provide different paths that firms may adopt when implementing their DT, while Szalavetz (2019, 2020) evaluates the implementation and implications of DT at subsidiaries of the MNE. Our exploratory theoretical paper, Fisch and Fleury (2020), is a theory elaboration paper using the first four articles from the list above. The recent articles support and complement the ideas introduced in Fisch and Fleury (2020). We also add Aldolphs (2015) as a starting point for areas where DT interacts with IOM and the implications from Blomqvist and Turkulainen (2019) described in Sections 2.3 and 2.4. The twelve articles reveal three DT strategies that we further explore in this paper: a) integration (ADOLPHS et al., 2015; BLOMQVIST; TURKULAINEN, 2019; CULOT; ORZES; SARTOR, 2019; GARAY-RONDERO et al., 2019; SZALAVETZ, 2019, 2020; TELUKDARIE et al., 2018); b) servitization (BLOMQVIST; TURKULAINEN, 2019; BRENNAN et al., 2015; CULOT; ORZES; SARTOR, 2019; SEINO, 2019; SZALAVETZ, 2019, 2020); c) relocation (BRENNAN et al., 2015; SZALAVETZ, 2019; STRANGE; ZUCCHELLA, 2017). We describe the DT strategies, their deployment as DT journeys and form our conceptual framework for this research in the following sections.

2.8.1 DT Strategy 1 –Integration

Digital technologies enable firms to integrate activities at the IIN level since they occur in a CPS or digital platform's virtual environment, while the execution materializes at the plant level, for example, on the floor of a plant (ADOLPHS et al., 2015;

BLUMQVIST; TURKULAINEN, 2019; TELUKDARIE et al., 2018). The networked nature of systems integration eliminates delays that did not allow effective real-time IIN-level integration in the past, providing real-time data sharing, interconnectivity, and rapid response across manufacturing processes (ADOLPHS et al., 2015; CULOT; ORZES; SARTOR, 2019; GARAY-RONDERO et al., 2019; SZALAVETZ, 2019).

Telukdarie et al. (2018, p. 323) propose an "integrated multinational total business solution" that integrates the entire IIN with real-time visibility, response, optimization, forecasting, and decision-making capabilities, in line with the evolutionary stages of visibility, transparency, predictive capacity, and adaptability from the "*Industry 4.0 maturity index*" (SCHUH et al*.,* 2017, 2020a). Other advantages of such a solution, according to Telukdarie et al. (2018), are the lower administration and operational costs, higher operational efficiency, lower level of mistakes generated by data errors, and higher standardization that allows the fastest global incorporation of upgrades and changes. By simulating the repair of a machine breakdown, Telukdarie et al*.* (2018) estimate a 3-fold time reduction between a fully automated I4.0 plant and a manual Industry 2.0 and a 20% reduction against an I3.0 facility.

Although rooted in the supply chain perspective, Culot, Orzes, and Sartor (2019) offer a functional data integration trajectory, useful under the IIN lens based on CPS and digital platforms, providing real-time capabilities like transparency, analysis, and decision-making. One player, a firm in the supply chain, or a plant in the IIN perspective, integrates all data from the network, coordinates specific activities like procurement, process planning, production planning, production scheduling, inventory management, or production-related like maintenance and quality (BLOMQVIST; TURKULAINEN, 2019; SZALAVETZ, 2019; TELUKDARIE et al., 2018). Culot, Orzes, and Sartor (2019) highlight that DT blurs functional boundaries, enabling higher integration of R&D, procurement, production, logistics, marketing, sales, after-sale services, and administrative functions like IT, finance, and human resources. The IIN may internalize or externalize, concentrate, or disperse activities with scale advantages for the entire network (CULOT; ORZES; SARTOR, 2019; SZALAVETZ, 2019). This process-centric digital strategy's main characteristic is integrating network activities, optimizing resources, agility, flexibility, and productivity for the entire network (SZALAVETZ, 2019). We propose that the type of integration above characterizes the IIN Integration DT Journey as follows:

The DT Journey of IIN INTEGRATION creates CPSs and internal digital platforms that connect, in real-time, a manufacturing function across the IIN, and different manufacturing functions at the site and IIN levels, improving the IIN's agility, flexibility, and productivity.

The distinguishing characteristics of the IIN Integration DT Journey are: a) the extensive use of digital technologies to improve productivity (ADOLPHS, 2015; CULOT; ORZES; SARTOR, 2019); b) the presence of the internal digital platforms integrating functions or activities at the IIN level (TELUKDARIE et al., 2018), c) the IIN-level coordination of such functions and activities at a single site (BLOMQVIST; TURKULAINEN, 2019; CULOT; ORZES; SARTOR, 2019), d) blurring of functional boundaries (CULOT; ORZES; SARTOR, 2019)

Adolphs et al. (2015) and Szalavetz (2019, 2020) underline the optimization of R&D processes as a key benefit from the DT through the life-cycle dimension. The integration across the life cycle of a product occurs when R&D works jointly with its innovation ecosystem, including external partners and other functions of the MNE like production, logistics, or marketing using innovation platforms for new product and services development, identification of process and product design issues, or emerging trends on customer preferences (ADOLPHS et al., 2015; CULOT; ORZES; SARTOR, 2019; SZALAVETZ, 2019, 2020). This way, plants that previously only executed production activities may incorporate higher-order activities into their portfolio (SZALAVETZ, 2019, 2020). The higher life-cycle integration suggests that R&D centers are now active inside the IINs, independent of their manufacturing sites' co-location. Moreover, R&D centers gain the capability to spread and intensify research and development activities by coordinating digital industry platforms that support stronger and broader innovation ecosystems (DE VASCONCELOS GOMES et al., 2018; GAWER, 2014; SZALAVETZ, 2019, 2020).

Ferdows' model only considered R&D or any other activities when executed inside the factory, excluding R&D or other sites that did not own any production. R&D centers can coordinate activities dispersed across its innovation ecosystem to develop new products and service offerings, integrating subsidiaries, customers, internal and external partners, thanks to CPS and industry platforms (BERTOLA; TEUNISSEN, 2018, GAWER, 2014). DT also allows closer proximity to customers that become part of the innovation ecosystem through the industry platform, supporting the design of customized products and services, enhancing the firm's value creation (BERTOLA; TEUNISSEN, 2018). The previous arguments suggest that the Integration DT strategy with a product-centric scope promotes a product/service life-cycle integration, leading to the proposition of our second DT journey.

> *The DT Journey of LIFE-CYCLE INTEGRATION promotes IIN and plant level changes by forming innovation ecosystems enabled by digital industry platforms to speed the development of new products, processes, systems, and service offerings.*

The Life-Cycle Integration DT Journey's elements are a) the intensive use of digital technologies to speed R&D activities (ADOLPHS et al., 2015); b) the presence of digital industry platforms (BERTOLA; TEUNISSEN, 2018; GAWER, 2014); c) the formation of innovation ecosystems including R&D centers, manufacturing functions, suppliers, customers, and other external partners (ADOLPHS, 2015; SZALAVETZ, 2019, 2020); d) the dispersion of R&D activities across the IIN and the innovation ecosystem (ADOLPHS et al., 2015; CULOT; ORZES; SARTOR, 2019; SZALAVETZ, 2019, 2020).

2.8.2 DT Strategy 2 - Servitization

Smart products enhanced with digital technologies allow firms to offer digitally enabled services that require real-time data management, agile and flexible servicing, and eventually a change in the business model (BAINES et al., 2017; FRANK et al., 2019; CULOT; ORZES; SARTOR, 2019). Although a recent phenomenon, servitization counts with a rich academic literature. A search of the "*serviti?ation*" term in the Scopus database returns 579 articles. Tim Baines, the most frequent author in servitization, has authored or co-authored literature-review papers on servitization that received over two thousand citations (BAINES et al., 2007, 2009, 2017; LIGHTFOOT; BAINES; SMART, 2013).

Vandermerwe and Rada (1988) were the first to coin the term "Servitization," a research topic in different communities like Services Marketing, Services Management, OM, Product-Service Systems, and Service Science, the latter having evolved from Information Systems, according to the literature review from Lightfoot, Baines, and Smart (2013). Lightfoot, Baines, and Smart (2013, p. 1412) define servitization as "*the innovation of a manufacturing organization's product and service* *offering that delivers value in use*." In OM, Brennan et al. (2015) describe servitization as an end-to-end approach that starts with R&D and affects all steps through after the use of a product or service.

DT has significantly improved the servitization transformation speed (BAINES et al., 2020), allowing firms to upgrade their offerings beyond traditional products (SZALAVETZ, 2019). Technologies like IoT, CC, and BDA allow firms to offer a range of advanced services instead of just selling products (FRANK et al., 2019; SZALAVETZ, 2019, 2020). Xerox provides an example of the servitization transformation involving DT (VISINTIN, 2014). It started with an Industry 2.0 model of leasing the equipment and charging for the photocopies in the 1960s, evolved to an I3.0 model where representatives managed single-site networks of multifunctional printers in the 1990s, and finally reached an I4.0 model where Xerox manages multi-site networks from helpdesk offices using CPS and digital platforms. At the same time, customers can also access the networks from their offices, homes, or any location worldwide (VISINTIN, 2014). DT also altered Xerox's business model, which now offers advanced business services like document management, human resources, reimbursement, accounting, and customer care services that also make extensive use of the helpdesk offices (VISINTIN, 2014; YIN; STECKE; LI,2018).

The aircraft industry is another well-documented servitization case in academic literature, as pointed out by Lightfoot, Baines, and Smart (2013) in their literature review of the subject. In the late 1990s, American Airlines requested Rolls Royce to offer a package that would pay by the hour flown by an engine, a risky and potentially disadvantageous model for Rolls Royce by then (BAINES; LIGHTFOOT, 2014). Only when technology-enabled real-time CPS directly connected in-flight engines to Rolls Royce systems would the model become profitable (BAINES; LIGHTFOOT, 2014; VISINTIN, 2014). Today, Rolls Royce makes over 50% of its revenue out of services coordinated by a monitoring center in Derby, UK, while a network of local service centers delivers the service to customers at their operational hubs like Texas, Singapore, and Hong Kong (BAINES; LIGHTFOOT, 2014).

In the servitization transformation (BAINES et al., 2020), IINs incorporate a business ecosystem that provides service offerings in addition to physical products. Control centers like Xerox's helpdesks and Rolls Royce's center in Derby monitor products in the field in real-time, while service provision occurs locally (BAINES et al., 2009;

SEINO, 2019; VISINTIN, 2014). This IIN configuration and coordination mode shortens inspection and repair times, lowers service costs, and improves the entire system's reliability and productivity (BAINES et al., 2020; GOVINDARAJAN; IMMELT, 2019; MARTINEZ et al., 2010). Servitization is in line with Casella and Fomenti's (2019) findings of lowering figures of foreign direct investment in the digital era since lightweight service centers require fewer inversions than manufacturing plants. The integration of product and service offerings requires a network that considers both types of operations, production and service offering, while traditional manufacturing models like Ferdows' or Shi and Gregory's only consider production sites as part of the IIN (FERDOWS, 1997; SHI; GREGORY, 1998). IINs can also offer economic platforms like e-commerce to expand business ecosystems, integrating plants, logistics structure, customers, and external partners to enhance the opportunities to do business and capture value (DE VASCONCELOS et al., 2018; GAWER, 2014; TSUJIMOTO et al., 2018). Servitization is a business-centric strategy that results in the DT Journey of Digitally Enabled Servitization as we propose below:

> *The DT Journey of DIGITALLY ENABLED SERVITIZATION will favor incorporating digital service offerings into manufacturing firms with a corresponding change in the IIN's configuration and plant roles to improve value capture using business ecosystems.*

The characteristics of the Digitally Enabled Servitization DT Journey are a) the incorporation of digital service offerings (BAINES et al., 2020); b) the introduction of digital economic platforms (GAWER, 2014); and c) the formation of a services-oriented business ecosystem, including the central coordination of the platform and a network of service delivery sites (DE VASCONCELOS et al., 2018; GOVINDARAJAN; IMMELT, 2019; SEINO, 2019; TSUJIMOTO et al., 2018).

2.8.3 DT Strategy 3 - Relocation (Backshoring, Reshoring)

A typical phenomenon from the third industrial revolution, offshoring production to low-wage countries, gained drive in the 1990s and early 2000s but suffered a reduction since the 2008 crisis (KINKEL, 2012). On the other hand, reshoring is associated with the correction of a failure to offshore but may also be a strategical decision in multinational firms' evolution (BARBIERI et al., 2018; BRENNAN et al., 2015; KINKEL, 2012). Ancarani, Di Mauro, and Mascali (2019) analyze back shoring initiatives from European firms in the light of DT, concluding that the need for higher customization, flexibility, and agility to respond to customers' requirements is a crucial strategic reason, in line with Brennan et al. (2015). Digital technologies such as 3-D printing and collaborative robots play an important role in counterbalancing low-cost labor and enabling production reshoring through innovative business models (ANCARANI; DI MAURO; MASCALI, 2019; BARBIERI et al., 2018; BRENNAN et al., 2015). Allied to digital platforms that empower the end-user to customize products, digital technologies promote the relocation of manufacturing, prioritizing the proximity to markets to reduce costs and delivery time (BRENNAN et al., 2015; STRANGE; ZUCCHELLA, 2017).

The apparel industry illustrates the relocation of production from low-cost remote locations to plants closer to markets. After offshoring production in the 1990s and 2000s, the apparel industry reversed the trend to improve quality, meet ever-increasing customization requirements by customers, and even counter environmental and social adverse effects of low-cost countries (BERTOLA; TEUNISSEN, 2018). By implementing DT, apparel companies intend to build smart factories, speed prototyping, increase agility, and focus on customers' requirements to develop new products. For that purpose, the industry uses 3-D printing, collaborative robots, and automated systems to manufacture their customized products. Another strategy is to build a network of interconnected modular small volume production sites that may become predominant in the future (BERTOLA; TEUNISSEN, 2018). Relocating production closer to markets improves the IIN's capability to capture the tacit market and operational knowledge for the IIN, besides quickly adjusting to changing customers' requirements (BERTOLA; TEUNISSEN, 2018). Digital platforms connect customers directly to manufacturing sites, providing flexibility and agility for small, specialized sites to deliver customized products or services (CULOT; ORZES; SARTOR, 2019). The relocation business-centric strategy triggers the next DT journey:

> *The DT Journey of RELOCATION will increase the MNE's value capture by relocating production from low-cost locations to agile close-to-market production sites, focused on making customized products using digital technologies, changing the IIN's configuration and its plants' roles.*

Typify the Relocation DT Journey: a) the Backshoring or reshoring of production from low-cost to close-to-market locations (BRENNAN et al., 2015; STRANGE;

ZUCCHELLA, 2017); b) the intensive use of digital technologies like 3-D printing and advanced robotics to reduce production costs and increase flexibility (ANCARANI; DI MAURO; MASCALI, 2019; BARBIERI et al., 2018; BRENNAN et al., 2015); c) the formation of business digital platforms to connect customers with the IIN (BERTOLA; TEUNISSEN, 2018); d) the formation of customization sites (ANCARANI; DI MAURO; MASCALI, 2019.

2.9 BUILDING THE CONCEPTUAL FRAMEWORK

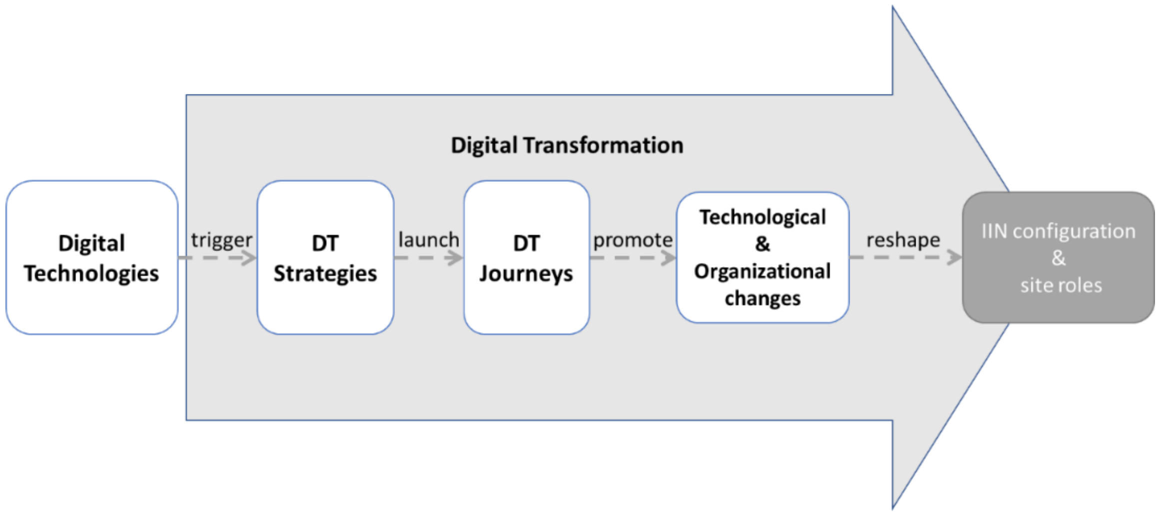
The four DT journeys above call our attention to changes in the IINs' configuration and coordination and plant roles in ways that the Ferdows' and Shi and Gregory's models cannot predict. New digital technologies inspire MNEs to build DT strategies and embark on DT journeys to gain a competitive advantage. By doing so, they open new avenues that may promote technological and organizational changes. IINs will reshape their configuration, closing operations that do not fit the digital era, opening new ones with specific activities enabled by digital technologies, or changing its coordination by altering the participating plants' roles. Figure 6 depicts the process we just described. There are implications to the existing models brought by DT. First, DT promotes a functional integration that blurs the traditional separation of R&D, production, and service networks. Second, the tradeoff between remote delay management and local higher-cost resources that differentiated plants in the model of Ferdows no longer exists in the digital era. Digitally enabled systems allow MNEs to remotely manage operations in real-time, removing an essential element in Ferdows' model, the opportunity for these plants to upgrade by taking expensive management activities to counterbalance the delays of remote coordination. Third, the increasing requirement for agility and flexibility favors plants located closer to markets because they respond to customers' changing demands faster. Fourth, digital technologies require that firms move their operations to locations with access to the required capabilities. All these implications suggest that the models from the 1990s require an update to explain such new contingency factors. We use the framework from Figure 6 and Table 7 to conduct our study following the research project that we will present in the next Chapter.

Table 7 - The Digital Journeys

DT Strategy	DT Journey	Characteristics or Elements	Primary strategic goal
Integration	IIN Integration	1. Digital technologies for productivity 2. Existence of Internal platforms 3. One site coordinates activities for all sites in the IIN 4. The blurring of functional boundaries	Improve productivity
	Life-Cycle Integration	1. Digital technologies for value creation 2. Industry platforms 3. Innovation ecosystems 4. Dispersion of R&D activities	Promote value creation
Servitization	Digitally Enabled Servitization	1. Digital service offerings 2. Digital economic platforms 3. Service-oriented business ecosystem 4. Centralized coordination, dispersed execution of services	Increase value capture
Relocation	Relocation	1. Backshoring or reshoring of production 2. Use of digital technologies to offset low-cost locations 3. Economic platforms 4. Customization of products and services	Foster the IIN's agility

Source: author

Figure 6 – The DT process, antecedents, and consequences



Source: adapted from Vial (2019)

3 RESEARCH PROJECT

3.1 CONTEXTUALIZATION

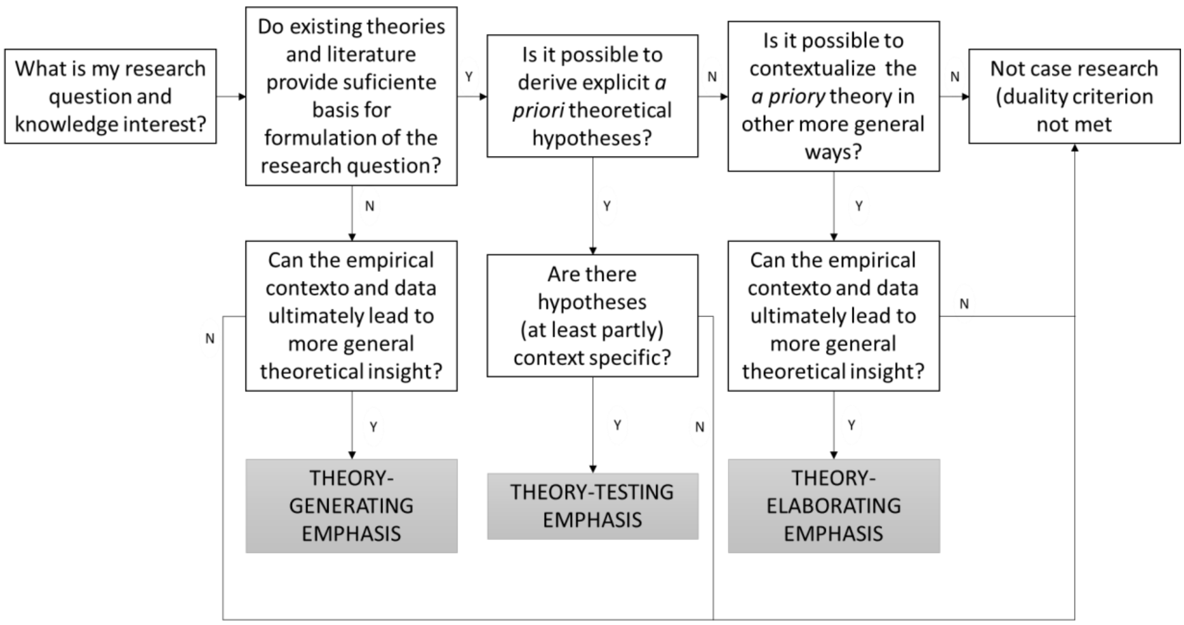
Chapter 2 developed the conceptual framework based on the literature review, fundamental for every research project to attain theoretical and conceptual rigor (ÅHLSTRÖM, 2016; CRESWELL, 2010; CAUCHICK MIGUEL; SOUZA, 2012). In this chapter, we build the research project following the guidelines organized by Cauchick Miguel et al. (2010) and Karlsson (2016), starting with the necessity of cohesion among the knowledge maturity, the research question, the methodological approach, and the expected contribution.

We investigate how and why a developing process, the DT as defined in Section 2.5.4, coevolves with the international operations of MNEs, reshaping the traditional models that represent the configuration and coordination of IINs, and the roles of their plants (FERDOWS, 1997; SHI; GREGORY, 1998). In other words, we are extending the existing IOM models by introducing the DT construct. However, merging the IOM and DT literature presented only a few papers according to Section 2.8 above. Therefore, we use the qualitative approach for the following reasons. Our research question starts with “how” and “why,” the research intends to explain and interpret textual data, the narrative matters, we explore ideas, the beginning is uncertain, each new version redefines ideas and findings, the research and writing are simultaneous, the process is iterative, and the elaboration of the back end forces the reshaping of the front end (BANSAL; CORLEY, 2012; CAUCHICK MIGUEL et al., 2010; KARLSSON, 2016; KETOKIVI; CHOI, 2014). We use case research, one of the most powerful methods in OM for the formulation of theories, since the phenomenon of study is recent, contemporary, not well understood, and we observe it in its natural environment (CAUCHICK MIGUEL; SOUZA, 2012; VOSS; JOHNSON; GODSELL, 2015, 2016; VOSS, TSIKRIKTSIS; FROHLICH, 2002; YIN, 2015).

3.2 SELECTION OF THE RESEARCH METHOD

There are several approaches to conduct case research. An inductive approach is a better fit for theory generation because its design facilitates theoretical insights to explain a phenomenon; a deductive approach works well for theory testing since existing theory generates hypotheses that require empirical confirmation; and an abductive approach is used for theory extension when observations are incongruent with existing theory (KETOKIVI; CHOI, 2014; CAUCHICK MIGUEL; SOUZA, 2012; VOSS; JOHNSON; GODSELL, 2015, 2016; VOSS; TSIKRIKTSIS; FROHLICH, 2002). When we use the decision tree from Ketokivi and Choi (2014) to select the best emphasis depending on the research characteristics, as shown in Figure 7, our research falls in the theory-elaborating or theory extension emphasis (KARLSSON, 2016; KETOKIVI; CHOI, 2014; VOSS; JOHNSON; GODSELL, 2015, 2016). The best design is abductive research that starts from literature, observes incongruencies with the current models, builds a new framework and a research protocol, tests the framework using empirical observations, improves the framework, and retests it until the empirical evidence matches the framework, confirming the extension of the original theory, as depicted in figure 8 (VOSS; JOHNSON; GODSELL, 2015, 2016). The abductive approach's main advantage is that it allows the analytical framework to evolve when confronted with empirical evidence, encouraging the research to go back and forth, incorporating learnings about the phenomenon under study from theoretical and empirical perspectives (DUBOIS; GADDE, 2002).

Figure 7 - Case research decision tree

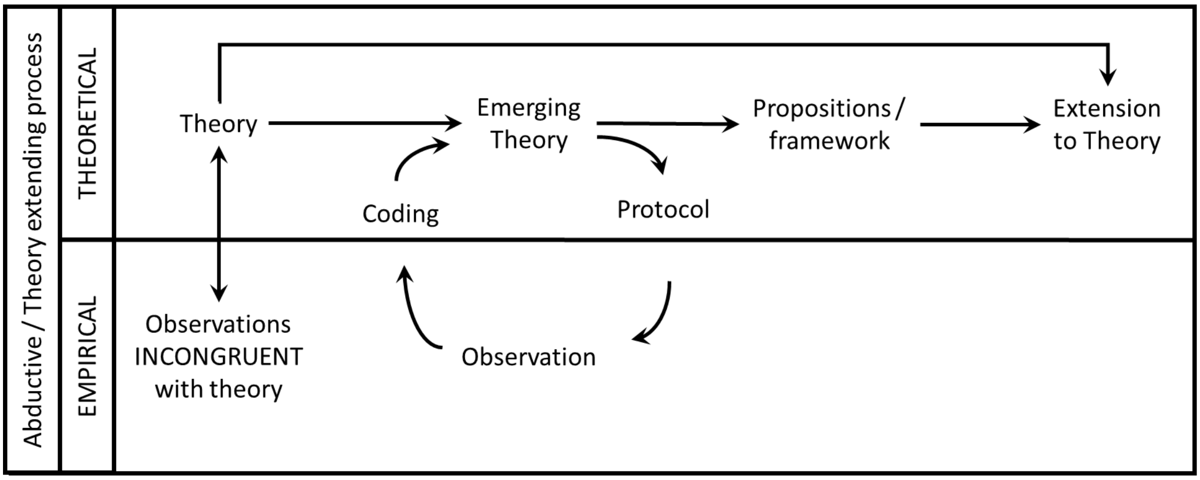


Source: Ketokivi and Choi (2014)

Bansal, Smith, and Vaara (2018) present several case research methodologies such as variance-based, process studies, action research, historical, and discourse studies.

These approaches have different assumptions to build theory, as they stem from different ontologies and epistemologies (BANSAL; SMITH; VAARA, 2018; GEHMAN et al., 2018; KARLSSON, 2016). For example, the realist ontology sees an organization as a universally accepted reality, while the constructionist ontology considers an organization as a social construct that differs from individual to individual (KARLSSON, 2016). Gehman et al. (2018) present three different qualitative approaches to case research, Denny Gioia, representing grounded theory, Kathleen Eisenhardt for comparative case research, and Ann Langley for process studies. In the following paragraphs, we present these three case research traditions and evaluate them against our research project to select the most appropriate approach for our study.

Figure 8 - The flow of abductive research



Source: Voss, Johnson, and Godsell (2015, 2016)

The most cited case research reference in OM and other management disciplines is Eisenhardt (1989). Based on a realist ontology, where theory represents the real world, her approach is variance-based and establishes well-defined constructs from the literature. Eisenhardt (1989) selects cases that present variations in these constructs of interest, establishes a priori control dimensions to all cases, and proceeds with a within-case analysis followed by a cross-case comparison to identify “surprises” to generate the insights for the construction of new theory. According to Eisenhardt (1989), saturation determines the number of cases, meaning that the researcher should add new cases until there is no new addition to the emerging theory. Eisenhardt argues that her template provides a close match between theory generation and theory testing (GEHMAN et al., 2018). The OM literature that uses case research refers to the template from Eisenhardt (1989), as well as to Yin (2015) on how to plan and conduct the case research, Miles, Huberman, and Saldaña (2014) for data coding and preparing data displays that support data analysis (BAINES et al., 2020; FELDMANN; OLHAGER, 2019; VERECKE; VAN DIERDONCK; DE MAYER, 2006). We use Yin (2015) to structure our research protocol and Miles, Huberman, and Saldaña (2014), to code data and display results.

Grounded theory is the second tradition in Gehman et al. (2018). Unlike the comparative case research from Eisenhardt (1989), Denny Gioia developed an approach to conduct grounded theory interpretative research based on a constructivist ontology. This phenomenological-cognitive approach intends to build theory by searching textual data from informants for similarities and differences, organizing the data into first-order categories or open codes, looking for a structure or theoretical-level second-order or axial coding that will generate the insights for further theory building (GEHMAN et al., 2018; GIOIA; CORLEY; HAMILTON, 2013; STRAUSS; CORBIN, 1990, 2008). Grounded theory dismisses any pre-existing conceptual framework. Instead, it builds theory from data (GEHMAN et al., 2018; STRAUSS; CORBIN, 1990, 2008). When interviewing more informants results in no further new information, saturation occurs (STRAUSS; CORBIN, 1990, 2008). The grounded theory coding process supports finding the insights or “surprises” for theory development for other methodological approaches, according to Eisenhardt and Langley (ABDALLAH; LUSIANI; LANGLEY, 2019; EISENHARDT; GRAEBNER, 2007; GEHMAN et al., 2018; LANGLEY, 1999). Therefore, we also use the coding process from Strauss and Corbin (2008) and Gioia (GIOIA, CORLEY; HAMILTON, 2013) as the inductive part of our data analysis. It is important to note that we are not doing grounded theory but using some of its tools to voice the informants.

According to Ann Langley, process research represents the mechanist-historic approach, the last tradition in Gehman et al. (2018). The focus of process research is to look for similarities and differences in the longitudinal development of a process to identify its mechanisms and patterns (GEHMAN et al., 2018). Instead of cross-case construct variation from the comparative case research or variation in interpretations from the grounded theory, process research intends to build theory by observing how a process evolves as a sequence of events, activities, temporality, and flow (GEHMAN et al., 2018; LANGLEY et al., 2013). The process research methodology "accommodates various ontological and epistemological commitments" (ABDALLA, LUSIANI; LANGLEY, 2019:92). The main ontological difference in process research is how the researcher pictures the social world, either as substantial entities – things - that are transformed by processes or as a collection of processes that evolve (LANGLEY et al., 2013).

After presenting the three research traditions based on Gehman et al. (2018), we can evaluate which best fits our research project. Our research question, *"Why and how does DT rearrange the configuration of the IIN and the roles of its plants?"* intends to study the DT, "*a process that aims to improve the MNE by triggering significant changes to its IIN configuration and plant roles through combinations of digital technologies*" according to the definition we developed in Section 2.5.4. From an ontological standpoint, we study a *process* (DT) that promotes *changes to entities*, the IIN's configuration and coordination, and its plants' roles. This process's starting point is a previous industrial stage with no or isolated digital technologies, with an ending point defined as "an interconnected smart enterprise of the I4.0 era" (FRANK et al., 2019:141). It is clear now that this research is process research, abductive in nature, as depicted in Figures 7 and 8 above.

The last step in the research approach's definition is to select the type of process research for our project. Abdallah, Lusiani, and Langley (2019) propose four different approaches for process research based on differences in their ontology basis: a) evolutionary process stories have a substantive worldview, in line with our research, b) performative and c) narrative process stories imply a processual view that does not match our research, and d) toolkit-based process stories follow Gioia's methodological approach that is not a good fit for our research project since our research expands already existing models. Therefore, our research follows an evolutionary process story approach. OM authors use this type of research but name it under the generic label "case research." For example, Baines et al. (2020) study the servitization transformation, Blomqvist and Turkulainen (2019) investigate the evolving relations of IINs and their plants, Cheng, Farooq, and Johansen (2011), and Feldmann et al. (2013) investigate how a change in a plant role affects the other plants, the IIN configuration, and its coordination.

3.3 DEVELOPING THE RESEARCH PROJECT

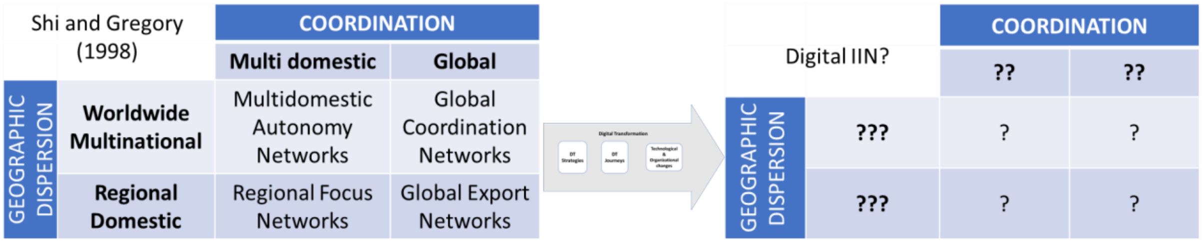
After deciding our research approach, we proceed to develop the research project through a sequence of activities based on recommendations from Cauchick Miguel and Souza (2012), Voss, Johnson, and Godsell (2015, 2016), Voss, Tsikriktsis, and Frohlich (2002), and Yin (2015):

a) Select a theoretical-conceptual framework;
b) Plan the cases;
c) Develop the research instruments for data collection;
d) Build the research protocol;
e) Conduct the field research;
f) Analyze and interpret data;
g) Check and validate the research reliability;
h) Report the findings.

3.3.1 Theoretical-conceptual framework

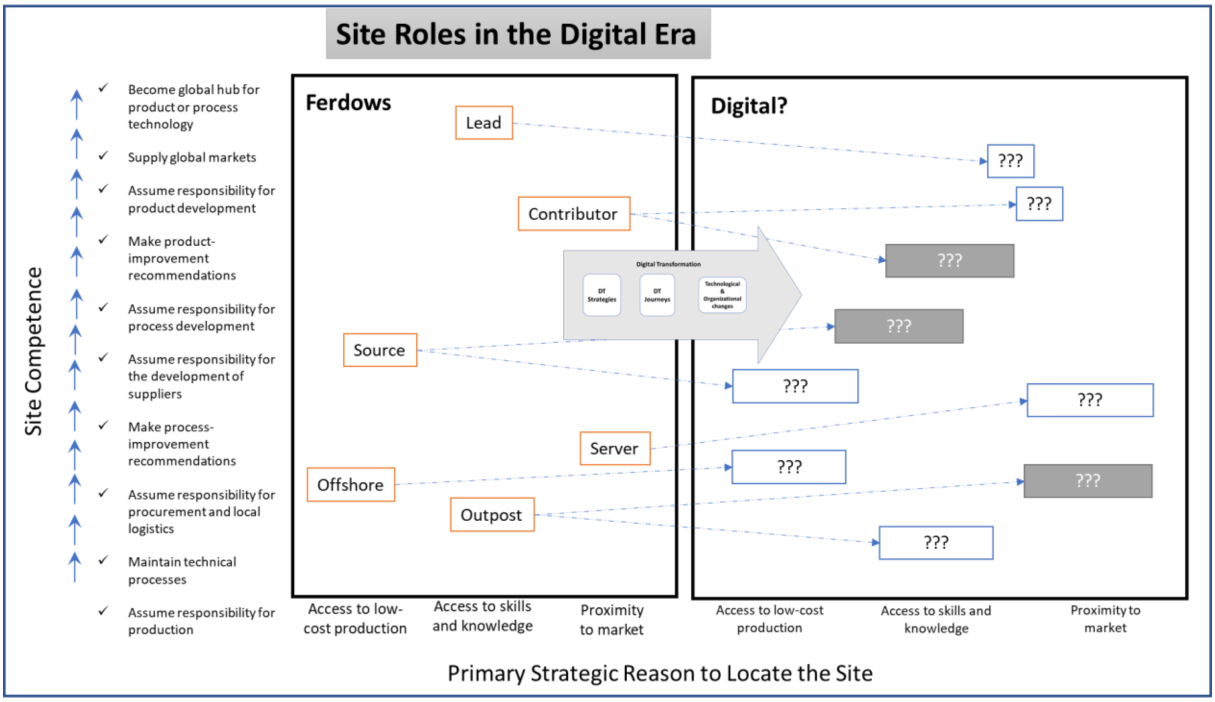
The first activity is the selection of the theoretical-conceptual framework. We have developed most of it across the previous Chapters of this work. Chapter 1 presents the research problem, the formulation of the research question, and the research objectives. Chapter 2 reviews the extant literature on IOM in Sections 2.3 and 2.4, DT in Sections 2.5 and 2.6, DT strategies in Section 2.7, and DT journeys in Section 2.8 to build the conceptual framework in Section 2.9. While reviewing the IOM's literature, we also identify two units of analysis to answer our research question, the IIN, and the plant levels. In Sections 3.1 and 3.2, we identify our theoretical contribution as theory extension, the type of research as abductive, and the research method as evolutionary process research, in line with other works in OM (BAINES et al., 2020; BLOMQVIST; TURKULAINEN, 2019; CHENG; FAROOQ; JOHANSEN, 2011; FELDMANN et al., 2013). To analyze the cases, we use the conceptual framework from Figure 6 in Section 2.9 above applied to the framework from Shi and Gregory (1998) at the IIN level, as shown in Figure 9 and the model of Ferdows (1997) for the site level, depicted in Figure 10.

Figure 9 - Evolution of the IIN configurations



Source: Author based on Shi and Gregory (1998)

Figure 10 - Evolution of the site roles



Source: Author based on Ferdows (1997)

3.3.2 Planning the cases

The second activity of the research project is to plan the cases. The theoretical-conceptual framework applies to Multinational firms (MNEs) that possess a network of operations (IINs) formed by several sites, each with different strategic locational motivators and different local activities. The longitudinal evaluation assesses a retrospective period between an initial state before DT and the research moment.

The selected cases should encompass IINs that are complex enough to contain plants with different roles to observe their evolution using the conceptual framework. These conditions cover our first two research objectives from section 1.4, understand the digital strategies and journeys to implement DT, the technological and organizational changes, and describe its outcomes in the configuration and coordination of the IIN and the role of its plants. The third objective is to learn how subsidiaries and operations in an emerging market evolve with DT, requiring selecting a specific research location. To comply with this objective, we restrict our research to local and foreign MNEs operating in Brazil, the “B” of the BRICS emerging markets (O’NEILL, 2011). The single-country context also controls potential cultural effects (BLOMQVIST; TURKULAINEN, 2019; VEREECKE; VAN DIERDONCK, 2002).

Besides the ease of access, allowing us to visit the operations, carry on interviews and make observations *in loco*, Brazil is an emerging country with the tenth largest global market and the best innovation capacity in Latin America (SCHWAB, 2018b). Brazil has a robust advanced agribusiness, an expanding services sector, and a complex industrial structure spread over the country. There is a significant presence of foreign MNEs operating in Brazil and a growing number of Brazilian MNEs (DIAS et al., 2019). There is also good informatics and communications technology (ICT) infrastructure supported by local and foreign firms. The internet dataflow is higher than the global average, and mobile phones align with the global average, characterizing the average Brazilian as a user of digital technologies and favoring DT's adoption (DIAS et al., 2019).

To complete the case planning, we should determine the number of cases that will take part in the research and the type of sampling to select them. Unlike quantitative research that requires a considerable random sample size, qualitative studies request theoretical sampling where specific reasons determine the cases. Single or few cases provide depth to the analysis, while multiple cases offer higher generalizability and external validity (VOSS; TSIKRIKTSIS; FROHLICH, 2002; VOSS; JOHNSON; GODSELL, 2015, 2016). Comparative case research typically requires between 8 and 12 cases to provide enough variation among cases (EISENHARDT, 1989; VOSS; JOHNSON; GODSELL, 2016). On the other hand, process research requires single or few in-depth studies because the comparison occurs in the longitudinal dimension (VOSS; JOHNSON; GODSELL, 2016). The challenge in evolutionary process research is to collect rich longitudinal information to capture the changes in the process studied (ABDALLA, LUSIANI; LANGLEY, 2019). Langley et al. (2013) suggest that the sample size's determination is related to the number of temporal observations, not the number of cases. Given the complexity of DT and the varied implementation journeys, a single case may not capture the process and its entire evolutionary paths, so we opt for multiple case studies.

We now turn to the four exemplar articles from section 3.2 to support us in building our case selection criteria. In common, they contain the following characteristics a) the existence of the process under study, b) evidence of changes caused by the process to the object of study, and c) specific criteria to delimit boundaries of the research. The criteria from Baines et al. (2020) are the evidence of the servitization transformation process, evidence of a trajectory towards advanced servitization, and avoid the selection of competing companies that might inhibit their willingness to share data. Bloomqvist and Turulainen (2019), and Cheng, Farooq, and Johansen (2011) select their cases based on the process to implement an IIN with operations abroad, with sufficient time for it to develop, and HQ in high-cost countries for practical reasons. Feldmann et al. (2013) justify selecting a single-case study based on the process's existence, the opportunity to accompany its evolution in real-time, and full access to top management, an unusual opportunity that justifies the single-case selection. Considering the discussion above, we use three criteria to select our firms: a) existence of a subsidiary and manufacturing plants operating in Brazil that belong to an IIN, b) potential to observe different DT processes and c) firms from different sectors for the same reasons stated by Baines et al. (2020).

The next step in the case selection activity is to search for potential firms. We start by identifying manufacturing sectors of interest, grounding our selection in the Standard and Poors' activity list, filtering for sectors with manufacturing activities like a) automobiles, b) automobile components, c) consumer staples, d) industrial equipment, and e) materials sector. For the identification of potential firms, and selection of the cases, we follow a similar process to Baines et al. (2020) that search, select, and establish a shortlist of companies through different techniques like the existence of known contacts, participation in association events related to DT, Linkedin networking, review of academic and business articles about Brazilian MNEs implementing DT. After the definition of the shortlist, we invite firms to participate in the research. Those who accept undergo confidentiality and access to data negotiations. Therefore, we must code the names of the MNEs as depicted in Table 8.

Table 8 - Overview of selected cases

CASE (origin)	Industry Sector	Size (Turnover and staff)	Sites in Brazil	Highest role of Brazilian site in IIN	Contact
A – LORRY (Europe)	Commercial vehicles	>USD 25 billion >75k employees	6	Contributor	DT managers
B – BUS (Europe)	Commercial vehicles	>USD 5 billion >20k employees	2	Lead	DT manager
C – CONFAST (Europe)	Consumer staples	>USD 50 billion >100k employees	9 + 20 M&As	Lead	DT director SC director
D – POWCAP (Europe)	Power&Energy equipment	>USD 25 billion >75k employees	10	Lead	DT manager Mfg mgr,
E – DIOCO (Europe)	Digital platforms	>USD 10 billion >25k employees	2	Contributor	DT director
F – RING (Brazil)	Automotive components	>USD 100 million	2	Lead	Indl. Dir. Ops/DT mgr
G – CROP (US / Europe)	Chemical – agro supplier	>USD 75billion >100k employees	2 + DC network	Lead	Site DT mgr

Source: author

The interviewees from the selected MNEs should be capable of answering questions related to the Brazilian subsidiary and plants, the IIN, and, when possible, to the foreign plants of that IIN. Managers and directors who lead the DT process in these MNEs fulfill these requirements. Voss, Johnson, and Godsell (2015) recommend the following actions to identify, contact, schedule, and execute interviews: a) identify a primary contact for each organization of interest, with sufficient seniority to offer support to the research and indicate the best resources for the interviews; b) list the informants that can be employees, alumni, suppliers, key customers, or other persons like digital platform users; c) contact the informants to schedule the interviews; d) ensure the disclosure of ethical considerations about data collected and their use to all participants; e) execute the interviews. We also submitted the transcripts to the respondents to confirm our reports' correctness, in line with Baines et al. (2020) and Blomqvist and Turkulainen (2019).

3.3.3 Data collection planning - Research instruments

Once the activity to plan cases is complete, the next activity consists of developing the research instruments and data collection protocols. We follow recommendations by Cauchick Miguel and Souza (2012); Voss, Johnson, and Godsell (2015; 2016); Voss, Tsikriktsis, and Frohlich (2002), and Yin (2015) to organize this activity, documented in the research protocol we introduce in Section 3.3.7 below and present in Appendix A. The main research instrument is the questionnaire based on the constructs' operationalization. Differently from Eisenhardt (1989) and Yin (2015), process research involves longitudinal instead of cross-case comparison. This research's abductive nature also implies a back-and-forth movement between the theory and empirical worlds that constantly evolves the analytic model.

In Appendix A, we present the questionnaire built upon our final model's constructs, developed along with the field research. Using this logic, we adjusted our research framework across the first round of interviews until we reached the final version from Figure 6 in section 2.9. In the second round of interviews, we identified missing data and tailored our questionnaires to the case under study and the interviewed informant. Appendix B displays an example of a second-round questionnaire. We now describe the operationalization of data collection using our conceptual framework from Figure 6 in Section 2.9. The following paragraphs introduce the constructs and their identifiers to characterize the DT strategy, the DT journey and changes, the evolution of the IIN configuration and coordination, and the reshaping of the IIN plants' roles.

The first set of data intends to characterize the MNE, its Global and Regional IINs, and its Brazilian operations. We look for data on the MNE origin, sector, the products and services offerings, the revenue, the volume, and the number of employees to dimension the firm's global and local sizes and operations in Brazil. We also look at the history of the MNE and its Brazilian operations to describe their evolution. This data comes from an initial search of secondary data from public information, typically the MNE's website and other publications. We collect any missing information in the interviews together with the identification of the informants.

Follows the DT strategies the MNE is implementing. In line with Sony (2018), we use strategic drivers to characterize each type in our model. Productivity improvement characterizes process-centric strategies. The development of new products and service offerings typify product-centric strategies. For business-centric strategies, we use integration with clients and markets. Our questionnaire has an open question to cover this point. Depending on the respondents' answers, we direct further questions to specific DT strategies.

Table 9 – Constructs and Identifiers

CONSTRUCT	IDENTIFIER
MNE and IIN	a) General data – origin, product and service offerings, volume, # employees b) Number and location of operations – global, regional, and/or local
DT strategy	a) Integration (process or product-centric) b) Servitization (business-centric) c) Relocation (business-centric)
DT journey	a) IIN Integration (digital technologies for productivity; internal platforms; single-site coordination of former plant-level activities; blurring of functional boundaries). b) Life-Cycle integration (digital technologies for value creation; industry platforms; innovation ecosystems; dispersion of R&D activities). c) Digitally Enabled Servitization (Digital service offerings; digital economic platforms; service-oriented business ecosystem; centralized coordination, dispersed execution of services). d) Relocation (Backshoring or reshoring of production; use of digital techs to offset low-cost locations; economic platforms; customization of products and services)
Technological and Organizational Changes	a) Technology dimension (digital technologies, CPSs, and digital platforms – industry, economic, internal) b) Organization (lean, DT leader, cross-functional collaboration, cultural adjustment initiatives)
IIN configuration – geographical dispersion	a) Local or Regional (1 country or 1 region) b) Multinational or Global (several regions)
IIN configuration – coordination	a) Multi-domestic (high site autonomy) b) Global (strong global coordination)
Plant role – Strategic reason to locate	a) Access to low-cost production b) Access to capabilities and knowledge c) Proximity to market
Activities hierarchy [1]*Includes service delivery (DT journey servitization)* [2]*Activity added according to DT journey integration*	a) Make products or deliver services[1] b) Management of manufacturing systems and digital platforms[2] c) Develop and improve systems, processes, and products. d) Hub for the development of specific components, products, or processes. e) Development and contribution to the company's knowledge. f) Center of Excellence – partners with the HQ in building strategic competencies

Source: author

We assess the DT from two perspectives. The first is the type of program implemented according to the DT strategies. We use a general open question to identify the digital journey of the MNE so that informants are free to tell their own stories. As follow-up questions, we ask about the integration of activities and functions, life-cycle integration, servitization programs, and production relocation to confirm the existence of each of the four DT journeys from our model.

DT's second perspective intends to evaluate the technological and organizational changes by adapting the four dimensions of the “Industrie 4.0 maturity index” from Schuh et al. (2017; 2020a). The dimensions of resources and information systems represent the technological evolution, and the dimensions of organizational structure and culture denote the organizational changes. Schuh et al. (2017; 2020a) only present the dimensions and critical metrics without further details. We use the questionnaire from Fleury et al. (2019) for a survey on Brazilian MNEs, and the Singapore Economic Development Board questionnaire (SINGAPORE, 2018), both based on the Acatech model, to build open questions for our qualitative research. We also review the questions from the on-line survey from Price-Waterhouse-Coopers (PWC, 2016) to complete our open questionnaire available at the research protocol in Appendix A. The longitudinal perspective evaluation uses the same technique as Feldmann et al. (2013) and Vereecke and Van Dierdonck (2002). For each question, we request the respondent to answer considering the period before DT, the interview moment, and an estimation of the future perspective. Respondents also should describe how and why each change occurred, what challenges they found, how they addressed them, and what benefits came out of DT. The questions intend to let respondents free to tell their stories. If they miss any of the items listed in the open questionnaire, we ask follow-up questions to ensure we get the desired data.

The last box of the model in Figure 6 represents the IIN configuration, coordination, and plant role changes. The questions intend to capture the longitudinal dimension by asking the informants about evolution before and after the DT process. We deliberately use “how” and “why” questions so that the informants can tell us what they consider the starting and ending points of their DT efforts. The IIN configuration and coordination modes follow the dimensions and construct definitions from Shi and Gregory (1998). We collect data on the first dimension, geographic dispersion of the manufacturing operations, in the initial website search to classify the MNE into one of four types, a) national, b) regional, c) multinational, and d) worldwide. We cover the second dimension, coordination between the IIN operations, with a specific question to classify each IIN as multi-domestic, where each operation has a higher degree of autonomy, or global, where central coordination is strong and individual operations have a low degree of autonomy (SHI; GREGORY, 1998).

Two dimensions define the following construct, the plant's role, according to Ferdows (1997), the strategic reason to locate, and the activities executed at the plant. We use the three strategic motivators for a plant to locate from Ferdows, the access to low-cost resources, the proximity to market, and the access to knowledge and capabilities (FELDMANN; OLHAGER, 2013; FERDOWS, 1997; VEREECKE; VAN DIERDONCK, 2002). For their case studies, Meijboom and Vos (2004) operationalize the strategic reason to locate dimension by using straightforward questions, replicated in Cheng, Farooq, and Johansen (2011) and our questionnaire in Appendix A.

The second dimension to characterize the plant's role is the set of activities it executes. We discussed this dimension in Section 2.4.4 and summarized the existing literature in Table 2. We adapted the hierarchy of activities from Vereecke and Van Dierdonk (2002) for our research because it is the most direct validated list. Our adjustments consist of a) generalizing the first level to include services, in line with DT journey servitization, and b) adding a new activity called “management of manufacturing systems and platforms” to reflect our discussion on the two DT journeys launched by the Integration DT Strategy. Table 9 summarizes this section and provides the initial codes for further processing of data. Both questions addressing the strategic reason to locate a plant and its activities intend to answer how plants' roles evolved with DT.

3.3.4 Carrying out the field research

Data collection follows Cheng, Farooq, and Johnson (2011). For each selected case, we start with a secondary source search looking for data related to products and services offered, location of operations, indicators of size like revenue and number of employees, the Brazilian subsidiary longitudinal evolution, and any DT evidence. For that purpose, we look at the companies’ global and Brazilian websites, look for documents that provide such data as annual reports, presentations to investors, customers, or stakeholders, press releases, interactive location and historical maps, academic and commercial publications. The secondary data source search forms a baseline to drive the most relevant data collection instrument in the case study, the semi-structured interview.

Semi-structured interviews provide in-depth knowledge of phenomena from primary sources (YIN, 2015). For reliability and validity purposes, we use the extant literature to develop the interview protocol from Appendix A, the respective questionnaire discussed under 3.3.3, and a summary of the research that we send in advance to our informants for their awareness and preparation (CHENG; FAROOQ; JOHANSEN, 2011; VOSS; JOHNSON; GODSELL, 2015, 2016; VOSS; TSIKRIKTSIS; FROHLICH, 2002; YIN, 2015). The typical interview starts with an introduction, proceeds with a quick review of the secondary data collected, and continues with the questionnaire's open-ended questions, complemented by additional questions once we identify new findings on the run. Most interviews last from one to two hours. Some cases require a second session with the same duration to complement data collection. A site visit takes place whenever possible. In general, two interviewers are present and take notes that they compile and combine with other support data forming an intermediate case summary. We prefer to take notes over recording interviews because we seek objective information from our informants, with no significant preoccupation with the exactness of what they say, a typical OM situation (VOSS; JOHNSON; GODSELL, 2015, 2016; VOSS; TSIKRIKTSIS; FROHLICH, 2002).

We send the summaries back to interviewees for verification, review, and correction, a process that makes use of further interviews, videoconferences, telephone calls, and e-mails. The cycles stop when we have enough data to build a complete case summary, and the informants agree with it without further inputs. Two main rounds of interviews occurred, the first one between September and December 2019 and the second one in the first semester of 2020. Due to the Covid19 pandemic, we used remote solutions to communicate in 2020. In total, we conducted twenty-two interviews, and four site visits totalizing thirty-eight hours of field work, complemented by secondary source searches, webinars involving the cases of study, phone calls, and e-mail exchanges to fine-tune the case reports.

3.3.5 Data analysis and interpretation methods

Data analysis takes place concurrently with the interviews, allowing the capture of insights from the collected data, the adjustment of the theory and the research protocol before moving back to the empirical world for further data collection, in line with the abductive nature of process research or longitudinal studies (KETOKIVI; CHOI, 2014; VOSS; JOHNSON, GODSELL, 2015, 2016). Data coding replicates the two-level process from Gioia, Corley, and Hamilton (2013) and Strauss and Corbin (1990, 2008), where first-order or open coding reflects the informant-centric terms or codes, and second-order or axial coding intends to aggregate primary codes using the researcher's constructs and dimensions, as well as new constructs that may emerge in this process. In line with the abductive approach, our coding process starts using an initial conceptual framework that evolves along the data collection and analysis process (DUBOIS; GADDE, 2002; VOSS; JOHNSON; GODSELL, 2015, 2016). Empirical data provides the first-order codes that we translate into second-order codes following our research protocol (Appendix A). Whenever the first-order codes fit the existing second-order codes, data support the framework. New insights drive the conceptual framework's improvement, originating new questions (see example in Appendix B) that initiate a new data collection cycle. The right column of Table 9 reflects the final second-order codes we use in this research, while the left column is the aggregate dimensions we want to evaluate. Appendix C presents a sample of the coding process. After coding the data, we develop the case summaries describing the IINs' and plants' evolution, indicating what the traditional models fail to explain. In Appendix D, we present each case in the following format: a) data sources; b) introduction to the case; c) the MNE and its operations in Brazil; d) DT strategies and journeys; e) IIN-level evolution under the model from Shi and Gregory; f) plant-level analysis and evolution under the model from Ferdows. The complementary nature of different sectors' cases allows us to form a broader picture of the DT process.

3.3.6 Research reliability and validation check

Another critical factor in data collection is to ensure its reliability. First, we build the constructs and identifiers from extant literature, ensuring previous validation. Second, we use triangulation activities to avoid biases from the informants and researchers. Whenever possible, there are two interviewers in each session and at least two informants per case. We turn transcripts of field notes into case summaries aligned by the researchers and then reviewed by informants to ensure the collected data's accuracy (VOSS; JOHNSON; GODSELL, 2015, 2016; VOSS; TSIKRIKTSIS; FROHLICH, 2002). After each interaction, the cycle begins with a secondary data source search described at the beginning of this section, this time to confront the case summary with available public information. In Chapter 4, we analyze the results, first confirming the conceptual framework's internal validity and reliability, then assessing the DT process impacts at the IIN and plant levels. (BLOMQVIST; TURKULAINEN, 2019; LANGLEY et al., 2013).

3.3.7 The research protocol and reporting

The research protocol describes collecting and analyzing data using tools like interviews, videoconferences, phone calls, e-mails, visits to plants, historical data review, firm websites, annual reports, and public digital platforms. Although Yin (2015) builds the protocol for comparative case studies, we use it for process research, taking the precautions to ensure we make the proper adjustments. Considering our research's abductive nature, we move between the theoretical and the empirical worlds. The conceptual frameworks and the protocol evolve with the research's progress.

Yin’s (2015) template contains the following sections: a) general view and intent of the protocol, depicting the protocol’s role and objectives, the research question, the analytical framework, theoretical model, and a brief description of the constructs, b) data collection procedures, starting with a brief review of the expected evidence the research intends to generate, continuing with the procedures to select data sources and collect data from each source, to select cases, to identify and communicate with contacts, to prepare and execute visits and interviews, and how to code the cases c) the semi-structured interview questionnaire, and d) guide for reporting the research, including data analysis and display. We combine this structure with Facin’s (2017) and Junior’s (2017) protocols to build our protocol template. The research protocol in Appendix A contains the choices and procedures we presented in this Chapter.

We used data gathered at the first round of interviews in 2019 to code, prepare the initial case summaries, and elaborate our conceptual framework. Data gaps varied according to the case, originating different semi-structured questionnaires for the second round of interviews. Appendix B displays an example of a second-round questionnaire, where the focus is to complete the gaps from the first round of interviews. To prepare our case summaries, we first coded our data using the procedures described in the previous sections in this Chapter, summarized in Appendix C. We prepared and submitted the final case summaries to our informants for their feedbacks, adjusted, and returned them until there was complete agreement on their content. Appendix D displays the final case summaries used for the analysis in the next Chapter.

4 FIELD RESEARCH ANALYSIS

In this Chapter, we analyze the evolutionary paths for each DT journey and expand the IOM models from the late 1990s using the seven case summaries of our fieldwork from Appendix D. Each case report describes how MNEs developed their DT strategies, implemented their DT journeys promoting changes that implied reshaping the IIN and its sites.

The intent of Section 4.1 is to provide internal validity for the framework we presented in Section 2.9, in line with Voss, Johnson, and Godsell (2015, 2016) and Yin (2015). We review how IINs implemented DT strategies through DT journeys, discuss the outcoming technological and organizational changes, and how they contributed to the success of each strategy.

Section 4.2 analyzes the IIN level implications based on the model from Shi and Gregory (1998). Even considering our cases' limitations, we propose that a new type of network coordination emerges with the DT process.

In Section 4.3, we present DT's implications at the site level, considering the model from Ferdows (1997). We highlight the changes of the higher horizontal, vertical, and life-cycle integrations of systems and functions based on empirical evidence. We discuss site roles' evolution and propose an expansion of Ferdows' model that we call the Digitally Enabled Multinational Inner Network – DEMIN. We present further empirical evidence from the business literature that supports our proposed model.

4.1 ANALYSIS OF THE FRAMEWORK - DT STRATEGIES AND JOURNEYS

In the following paragraphs, we use the seven cases from this study as empirical evidence to demonstrate the internal validity of the framework presented in Section 2.9. According to Voss, Johnson, and Godsell (2016) and Yin (2015), internal validity allows establishing a causal relationship. Considering that each DT strategy has a specific objective, we look at each DT journey, analyze the technological and organizational changes it promotes, and how these changes contribute to meeting the original DT strategy objective of the MNE. Table 10 illustrates the cases where each DT Journey was employed. The seven cases in this study reveal that the DT journeys contain all their distinguishing characteristics or elements, except for the Relocation

DT journey. The present analysis extracts the technological and dimensional changes, resulting in the outcomes that meet the DT strategy intents, in line with the conceptual framework from Table 7 and Figure 6 in Section 2.9. The following sections shed light on each DT journey, explaining how they adhere to or deviate from the conceptual framework.

Table 10 – DT Journeys per case

	DT Journey			
	IIN Integration	Life-Cycle Integration	Digitally Enabled Servitization	Relocation
A - LORRY	YES all elements	YES all elements	YES all elements	I4.0 line, no platform
B – BUS	YES all elements	YES all elements		
C – CONFAST	YES all elements	YES all elements	YES all elements	I3.0 line, no platform, niche customization
D – POWCAP	YES all elements			
E – DIOCO		YES all elements	YES all elements	YES – all elements
F - RING	YES all elements	YES all elements	YES all elements	I4.0 line, no platform
G – CROP	YES all elements		YES all elements	I3.0, no customization or economic platform

Source: Author

4.1.1 IIN Integration DT journey

We start with the IIN Integration DT Journey that stems from the process-centric Integration DT strategy. The framework predicts that this DT strategy intends to improve the production processes' productivity at the plant level and the corporate systems at the IIN level.

At the plant level, the implementation of I4.0 technologies in production illustrates the technological dimension changes with the formation of CPSs using sensors, IoT, CC, BDA, AI, augmented reality, cobots, and other machine-human interfaces, resulting in productivity improvements, agility, and flexibility to meet customers' requirements. Cases A, B, C, and F reported higher throughput and agility. Cases A, B, C, D, and F implemented function automation in quality inspections, production sorting, and packaging. The automation of production lines led to sharp operational staff reduction in cases A, B, and F, assembly, or modular production systems. In contrast, process industries that went through automation in the early 2000s suffered a smaller impact with the implementation of I4.0 technologies. Process optimizations led to energy, utilities, and steam usage reduction in cases A, B, C, F, and G.

At the IIN level, technological changes comprise the use of internal digital platforms integrating different activities. As presented in cases A, B, C, D, F, and G, one site manages activities like procurement, production planning, logistics, product life cycle, quality, maintenance, human resources, finance, and ICT for a group of sites or the entire IIN. The IIN Integration DT Journey transformed a collection of plants with weak analogic coordination into a real-time digitally integrated network. The main implication to the IIN is that activities previously managed at the plant level now occur at the network level. The location managing each activity may settle at any point of the network, as part of an existing manufacturing plant, like in cases A, D, F, and G, or as a stand-alone operation like case B’s global consolidation center and case C's control towers. The productivity gains stem from eliminating duplicate work from plants and better coordination at the IIN level, eliminating wastes like duplicate resources, delays, excess inventory, poor production scheduling, scrap, and machine breakouts.

There are also implications to the organizational dimension resulting from the IIN Integration DT Journey. The first noticeable implication, present in all cases, is the appointment of a DT leader from operations at plant and IIN levels, while ICT plays a technical support role. In cases A, B, C, F, and G, the DT leaders also report lean’s early implementation in the DT journey, typically at the digitalization steps corresponding to I3.0. The rationale is that lean focuses on eliminating wastes and streamlining work processes. According to our informants, implementing DT at inefficient and ineffective processes would only amplify loss and waste.

The use of multi-functional teams, integrating different functions and blurring functional borders, is also a characteristic of the DT Journey of IIN Integration, as reported in cases A, B, C, and F. Besides improving cooperation among different functions, such programs stimulate employees' proactiveness and promote a cultural change to foster the plants' DT journeys. There are new required capabilities to carry the new activities. Technical skills to operate the CPSs and internal digital platforms are mandatory. Other skills needed in the DT journeys are quick prototyping techniques to improve systems and manufacturing processes such as Proof of Concept, design thinking, A3, scrum. MNEs are also enabling their personnel in project management capabilities. To qualify their employees, MNEs implemented training programs, usually with external support like reported in cases A and B, intrapreneurship programs like in cases A, B, and C, and by hiring qualified resources in the market like reported in cases A, F, and G. In any of the cases above, proximity to knowledge and resources is critical to the success of the DT journey. At the IIN level, global networks align the glide path for their DT journeys, like in cases A, B, and C. The implementation of DT projects occurs in both top-down and bottom-up ways. In the first mode, the IIN designs a global project, and a plant assumes responsibility to implement a pilot. In the second mode, a plant initiates a pilot project to solve an issue, brings it to the IIN level, and, if approved, deploys the project to the rest of the IIN.

4.1.2 Life-Cycle Integration DT journey

Life-Cycle Integration differs from the IIN integration journey in its strategic intent. The latter originates from a process-centric Integration DT strategy focused on improving the IIN's productivity, and the former stems from a product-centric Integration DT strategy aimed at developing products, service offerings, and processes. R&D plays a central role in the Life-Cycle Integration DT Journey, converging data originated inside and outside the IIN.

In the Life-Cycle Integration DT journey, the primary phenomenon we observed is the dispersion of R&D activities into an active innovation ecosystem. Industry platforms enable R&D activities to disperse from the traditional R&D centers to many ecosystem participants, internal and external to the firm. Cases A, C, E, and F report the formation of an innovation ecosystem. The ecosystems integrate employees from several areas, digital engineers, external partners, and customers.

Fast prototyping using 3D printing, augmented reality, data repositories, BDA, AI, Product Life Cycle tools to develop, simulate, analyze products and processes before construction, and digital industry platforms for collaboration are typical technological dimension changes that bring together the development process stakeholders. In recent applications, like in cases B and E, the formation of the CPS starts with the digital part of the system so that, even before physical construction, digital tools improve the systems' effectiveness by forecasting interferences, process bottlenecks, and other situations that would require redesign or rework. Another advantage of starting with the digital part of the CPS is that digital shadow capabilities exist since the physical part inception. Overall, starting the digital part of the CPS speeds the development, construction, and start-up of the system, improving its on-going effectiveness.

In the organizational dimension, we observe the intensive use of fast development methodologies like Proof of Concept, Minimum Viable Product, Scrum, Squad, swarm, and A3. In many cases, these methodologies started with pilots involving multifunctional teams, as reported in cases A, C, and F. The success of the pilots encouraged the diffusion of fast development methodologies into the formal R&D structures. Though observed in individual cases, cultural adaptation programs reported in Case B and leadership efforts to remove organizational silos from case F seem to play an essential role in the integration process of R&D into the IIN. Co-location of R&D and production sites also improves the integration of R&D and production, as seen in cases A, B, C, D, and F.

Our cases show that the R&D and production function increased integration to meet the DT journey's objective. We observed variations according to the case. Cases B, C, E, and F are the most advanced, with R&D assuming responsibility for production activities like maintenance or quality. In contrast, production supports the development of new products and service offerings, a hybrid DT journey of IIN and Life-Cycle Integration. R&D gains speed to develop and deploy new products while production gains productivity by simplifying its production and service delivery systems.

Lastly, as we observed in cases C and E, the Life-Cycle Integration DT journey disperses ICT, a characteristic that was not part of our original framework. Initially concentrated in a single service provider, internal or external, the ICT function now uses several service providers according to the project's scope, forming an ICT innovation ecosystem. For example, in case C, traditional ICT MNEs, small companies, start-ups, freelancers, and internal resources provide solutions according to each project's complexity and size. In case E, the platform development sites join forces with an innovation ecosystem, including local resources like the training center, applications developers, and clients, to develop new solutions tailored to the customers’ needs.

4.1.3 Digitally Enabled Servitization DT journey

The Digitally Enabled Servitization DT journey follows a business-centric DT strategy. As described by Baines et al. (2020) and Frank et al. (2019), DT plays an essential role as an enabler of this DT journey. Cases A, C, E, F, and G reported different forms and levels of Servitization Transformation. In common, Digitally Enabled Servitization relies on business ecosystems of different sorts. In some cases, global R&D develops the hardware and software platforms that will support digital services, and the local ecosystem develops customized solutions for the local market, as we observed in cases A and E. Another form of digitally enabled servitization is the direct creation of applications for local markets that form digital platforms supporting business ecosystems. App-based digital services may target increased customer loyalty or support customers on regulatory or environmental questions like observed in cases A, F, and G. Other services aim to increase product sales, like the marketplace from case C and the digital platforms in case E.

In cases A, E, and G, there is the intense use of digital technologies. The platforms operate using sensors in the field, IoT, IoS, CC, BDA, and AI to optimize the offerings. Besides, the service providers in case G also use satellite photographing technologies allied to AI to generate a digital picture of the crops they monitor. The platforms' ownership may belong to the MNEs, like in cases A, E, and F, or third parties like in cases C and G. In common, cases A, C, E, F, and G rely on a control center to manage the digital platforms and a network of service centers to deliver the services.

The technological changes in digital servitization require the acquisition of capabilities that do not exist in traditional manufacturers. We observed different ways of capability building. Cases C and E report M&As, while case G informs partnerships. Case A develops its global service offerings internally, but we could not confirm how the MNE acquired the needed capabilities.

In the organizational dimension, the DT journey of servitization led to creating new divisions and sites, discontinuing operations in at least one MNE. Case A created a new division of services offerings at the IIN level and Site A4 in Brazil to manage the local service offerings in Latin America. Case C acquired an existing company to offer their new service, while case E discontinued the traditional manufacturing operation and incorporated new R&D capabilities through the M&A effort described in that case. Regarding case G, third-party service providers offer the services and connect customers, service providers, and the MNE. While there is the integration of hardware and software in case A by design since the inception of the program, the conglomerate that owns case E has recently promoted a DT strategy to integrate their hardware (manufacturing) and software (services) companies. Although belonging to the MNE, the service network in case C operates as a separate company, while the third-party providers are independent firms in case G. The variety of implementations suggests that the DT strategy of Servitization may unfold in different evolutionary paths.

4.1.4 Relocation DT Journey

The last DT Journey is Relocation. The empirical data suggests a different evolutionary path than the prediction of the conceptual framework. Although production relocation occurs in cases A, C, F, and G, it presents deviations from the framework's characteristics. The Relocation DT Journey appears as an outcome of the DT journey of IIN Integration. The extra production capacity of digital technologies enables I4.0-lines to concentrate production from several traditional lines, resulting in the absorption of production from other plants. The MNEs relocated production from former low-cost plants to the new I4.0 lines in cases A and F. Cases C and G reported the same effect using I3.0 technologies. One explanation is the difference in manufacturing systems. While cases C and G manufacturing consists of batch or continuous process lines, fully automated in the early digitalization of I3.0, cases A and F only enjoyed complete digitalization with I4.0 technologies. In all cases, on top of improving the cost and productivity of the IIN, the relocation of production approximates manufacturing from consuming markets, resulting in higher agility to meet customers' demands.

Noticeable is the absence of employing 3-D printing technologies and economic platforms to build a network of small customization sites, as proposed by Barbieri et al. (2018), Brennan et al. (2015), Kinkel (2012), and Strange and Zucchella (2017). In our cases, 3-D printing is present in prototyping, tooling, and spare parts manufacturing, but not in the manufacturing of finished products. A network of customization sites was present in case C only, where a series of M&As intended to promote niche products, implying the partial relocation of production from the traditional large plants to a network of small factories. Small customization plants offer more agility and flexibility to meet increasing customized product demand, in line with the proposal from Bertola and Teunissen (2018). Even in case C, we did not observe a business platform's formation to coordinate customization sites.

In the DT journey of relocation, the main change in the technological dimension is creating operations to cope with customers' new demands. In cases A, C, F, and G, the higher volume automated plants provide the agility and flexibility required for large production volumes but lack capabilities to meet individual customers' requirements.

For small, customized volumes, the niche acquisitions from case C intend to cover specific market tendencies. The testbed site in case E promotes customized solutions for customers, integrating an innovation and business ecosystem.

In summary, our field research provides evidence of production relocation to digitalized factories like cases A, C, F, and G, or the formation of a customization network like the acquisition of innovative companies for niche markets like case C or forming a business ecosystem for services customization like in case E. Our cases do not reproduce the apparel example in its integrity, suggesting that customization solutions will depend on the product, service offerings, and customers' profile.

4.1.5 Summarizing the DT journeys

The DT journeys analysis above aims to provide internal validation (VOSS; JOHNSON; GODSELL,2016; YIN, 2015) to the typology proposed in section 2.8. The empirical data supports the three DT strategies, the four proposed DT Journeys, and their primary strategic goals. The cases' observations also confirm the characteristics from the IIN Integration, Life-Cycle Integration, and Digitally Enabled DT Journeys presented in Table 7 but only some of the Relocation DT journey’s elements. Production relocation stems from the capacity increase resultant of digital technologies implementation, not to disperse production for customization. The presence of economic platforms occurs in only one case (case E). Therefore, the Relocation DT Journey characteristics require an update based on the empirical findings of our research. In Table 11, we updated the Relocation DT Journey’s characteristics to match our field findings. The first characteristic becomes “relocation of production or services” to recognize the relocation of service centers as observed in case E. We redefine the second and third characteristics as “use of digital technologies to improve agility and flexibility” to reflect that digital technologies, including an eventual digital platform, intend to gain agility. Finally, the fourth characteristic from Table 7 reads “improved capacity to make, customize, and offer a wider range of products or service offerings” to include relocation motivators that go beyond customization as expressed in the original statement.

Table 11 - The Digital Journeys

DT Strategy	DT Journey	Characteristics or Elements	Primary strategic goal
Integration	IIN Integration	i. Digital technologies for productivity ii. Existence of Internal platforms iii. One site coordinates activities for all sites in the IIN iv. The blurring of functional boundaries	Improve productivity
	Life-Cycle Integration	i. Digital technologies for value creation ii. Industry platforms iii. Innovation ecosystems iv. Dispersion of R&D activities	Promote value creation
Servitization	Digitally Enabled Servitization	i. Digital service offerings ii. Digital economic platforms iii. Service-oriented business ecosystem iv. Centralized coordination, dispersed execution of services	Increase value capture
Relocation	Relocation	i. Relocation of production or services ii. Use of digital technologies to improve agility and flexibility iii. Improved capacity to make, customize, and offer a broader range of products or service offerings.	Foster the IIN's agility

Source: author

Table 12 summarizes the analysis of the technological and organizational changes promoted by each DT Journey. Although there are significant differences, some of the changes overlap in different journeys, indicating commonalities. Besides, the field research suggests that DT journeys may be interdependent. For example, the IIN integration DT journey introduces changes that support other DT journeys. We discuss the potential implications of DT journeys' interdependence in the next Chapter. We further discuss the DT journeys' implications to the IIN level in Section 5.2 and the plant level in Section 5.3. highlighting the differences in the strategical intent, technological changes, and organizational changes

Table 12 - Technological and Organizational Changes

DT Strategy	DT Journey	Technological Changes	Organizational Changes
Integration	IIN Integration (Process-centric productivity improvement)	• Digital shadow or twin • Internal digital platform • I4.0 technologies – CPS in production • 3-D, AR, man-machine interfaces for maintenance and as support to operations	• DT leader from operations • ICT has a support role in DT • Lean precedes advanced DT • Process and system optimization before implementing advanced DT • Multifunctional teams • Activities coordination at IIN Level - One site manages specific activities for the IIN (planning, procurement, logistics, quality, maintenance, admin) • Intra and inter function integration • Quick prototyping techniques • Training & intrapreneurship • Talent acquisition
	Life-Cycle Integration (Product-centric faster development of products, processes, and services)	• Data repositories • An internal platform for data sharing within IIN • 3D printing for prototyping • Augmented reality for R&D • Industry digital platforms • Intensive use of digital technologies in product and process design (PLM) • The Digital part of CPS starts at the design phase	• Fast development methods • Multifunctional teams, • Innovation ecosystems - Internal & external partners • Capabilities through training, hiring, M&As or JVs • R&D assuming production activities and vice-versa • Type of ICT support by project
Servitization	Digitally-Enabled Servitization (business results improvements)	• Economic digital platform • Intensive use of digital technologies (I4.0, CPS) in products to enable service offerings • Apps & customer interfaces	• New service companies, divisions, or sites • Global R&D develops products and platforms • Local innovation ecosystem develops customized apps • Different models of servitization • Reshaping of the sales function • Business ecosystems to support services, boost sales or increase brand loyalty • New capabilities formation using: Training & Talent acquisition, M&As, and JVs
Relocation	Relocation (customer-centric agility, flexibility, customization)	• Digitalization of production: process industry in I3.0, assembly in I4.0 • 3D printing is not part of production processes • Intensive use of digital platforms	• Global plants (process industries) • Production relocation to digital plants closer to markets • M&As and JVs for customization • Testbed for new technologies • Difficulty to incorporate new operations into corporate culture

Source: Author

4.2 NETWORK-LEVEL ANALYSIS

This section analyzes the network-level changes, considering the limitations to the generalization that stem from our sampling, centered around Brazilian operations of four European and one Brazilian MNEs. Our field research did not identify observable changes in the first dimension of Shi and Gregory's model, the IIN configuration or geographic dispersion. There is a significant change in the coordination of the IINs in cases A, B, C, E, and G, while the remaining cases, D and F, present no observable change in coordination.

Changes in the geographic dispersion of an IIN could result from the Relocation DT journey. We observed that I4.0 technologies triggered production relocation from low-cost locations to plants closer to markets in at least two cases, A and F, while C and G this movement took place earlier in the 2000s using I3.0 digital technologies. Nevertheless, the affected plants did not shut operations but changed their roles inside the respective IINs. Consequently, the geographic dispersion of the IINs remained the same before and after the DT process. The Life-Cycle integration DT journey dispersed the R&D function. A wide range of partners joined the innovation ecosystem using industry platforms. The four cases that report the formation of an innovation ecosystem, cases A, C, E, and F, describe these partners as local providers for local solutions with no noticeable impact on the geographic dispersion of their IINs.

We also do not observe any noticeable change in the geographic dispersion of IINs that adopted other DT journeys. The global IINs remain multinational, while the regional or local IINs remain unchanged too. The IIN Integration and the Digitally Enabled Servitization DT journeys may result in new sites for the IINs under study, but they have little or no noticeable impact on the networks' geographic dispersion.

There is an observable change to the second dimension of the model from Shi and Gregory, coordination. Cases A, B, C, D, E, and G presented multi-domestic coordination before DT, with high autonomy of sites and weak or no coordination at the IIN level. The integration of functions, systems, and life cycle foreseen in the RAMI4.0 model (ADOLPHS et al., 2015), materialized with the IIN and Life-Cycle Integration DT journeys, improving the networks' interactions. Several activities previously executed at the plant level, like procurement, planning, logistics, ICT, administrative functions, quality, and maintenance, now occur at the network level.

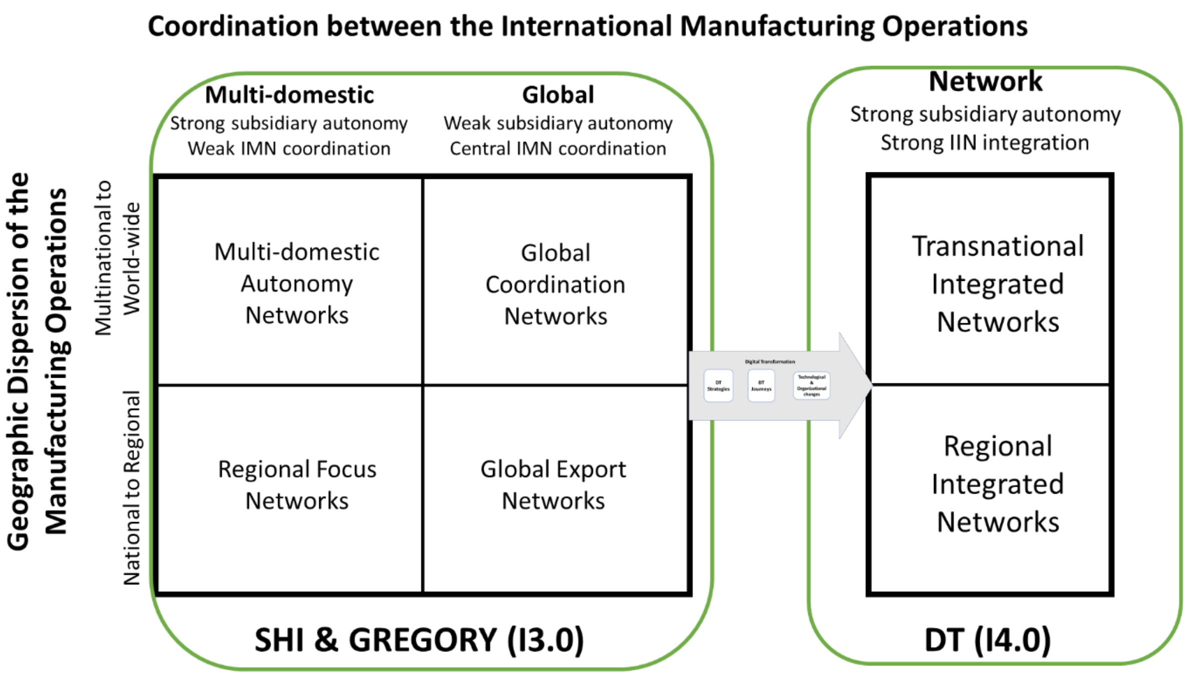
One site takes responsibility for those specific activities across the IIN. The communication and data flow occurs in real-time, updating systems and facilitating decision making at the IIN level instead of the traditional process where each site made isolated decisions. Global or regional teams discuss common issues and agree on further actions. Eventually, a more advanced site assumes the leadership of resolving the pending issue for the entire IIN, like observed in cases A, B, C, E, and, to a lesser extent, also for case G.

Unlike global coordination, where the lead site makes decisions and the remaining sites enjoy little or no autonomy, the DT process enabled a new form of coordination, dubbed Network Coordination. Sites are still autonomous but have an active voice in the IIN level decision-making process. The network coordination also moves activities from the site to the network level, as explained in the previous paragraph. The new coordination profile avoids duplication of efforts and improves flexibility, agility, and scale for the activities that now take place at the network level.

The Network Coordination maintains the autonomy of sites, permits decision-making at the IIN level with all its members' participation, and centralizes the management of activities at single sites, not necessarily the leader of the IIN. The DT journeys of IIN Integration and Digitally Enabled Servitization, present in cases A, B, C, E, and G, foster internal and business platforms supporting network coordination. We observed no change in Case D, still at the beginning of its DT journey. Finally, the only case with global coordination, case F, did not present any observable change in its coordination mode. Being a single case, we cannot conclude if this is a general trend or a specific development in case F.

Two new types of networks emerge with the Network Coordination, depending on the IIN's geographic dispersion. Multinational or worldwide dispersion creates a Transnational Integrated Network, while Regional or National dispersion creates a Regional Integrated Network. Our cases suggest that Multi-domestic Autonomy Networks will evolve into Transnational Integrated Networks, while Regional Focus Networks will evolve into Regional Integrated Networks like depicted in Figure 11. The main challenge of the evolution from multi-domestic to network coordination is the lack of standards developed along decades of weak central coordination and high subsidiaries' autonomy, as observed in IINs that went through this evolutionary path. On the other hand, global coordination should have provided higher IIN standardization but low autonomy at the sites. The challenge would be to improve capabilities for DT while giving up some of the central control. We theorize that global coordination IINs would also evolve into network coordination. Only case F had global coordination before DT. Although case F follows the DT journeys from our framework, the evidence collected in that single case is inconclusive about the evolution of global coordination networks.

Figure 11 - Evolution of the IIN's configuration

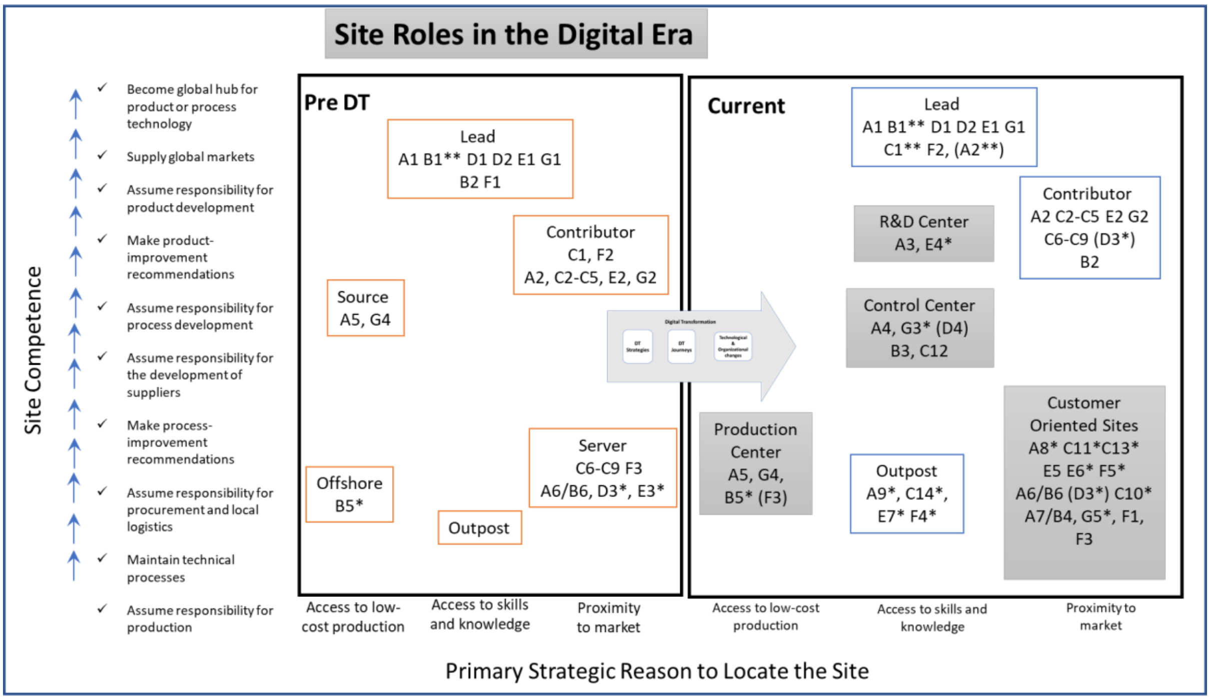


Source: the author

4.3 PLANT-LEVEL ANALYSIS – TOWARDS THE DEMIN MODEL

This section analyzes the site-level evolution using the case summaries from Appendix D. Figure 12 captures the site roles before and after DT using Ferdows' framework. The left frame contains the pre-DT site roles. All sites fit into one of the roles according to Ferdows' typology. Most sites fall into the Lead, Contributor, or Server roles indicating that the proximity to market and knowledge are the two main drivers for establishing plants in Brazil. The right frame depicts the site roles in their current state after our field research. Three site types maintain their names (Lead, Contributor, and Outpost), although their roles evolve with DT. Three roles (Source, Offshore, and Server) evolve in different ways in the new framework, while new types of operations emerge with DT, some evolving from Ferdows' plant roles, like the production centers that merged source and offshore roles, others related to activities carried at the IIN level, like control centers. The following sections analyze the impacts of each DT journey on the site roles. We use empirical evidence from our cases to explain the changes. After discussing the site-level evolution from the DT journeys, we propose an updated framework we call the “Digitally Enabled Multinational Inner Network” – DEMIN. We justify and describe each site's role in the new model, illustrating further evidence from the business literature when appropriate.

Figure 12 – Sites evolution before and after DT



Source: author

4.3.1 Impacts of the IIN Integration DT journey

CPS and internal digital platforms are the main technological changes in the IIN Integration DT journey. They foster intra- and inter-functional integration that enable the IIN to coordinate activities previously executed individually at the site level. The empirical evidence indicates that Lead and Contributor sites that capture some of the IIN-level activities' coordination reinforce their role since they concentrate functions removed from the other plants in the IIN. There is also evidence that Contributor Sites may upgrade to the Lead role, as observed in cases B and C.

Starting with evidence for the Lead role, Site A1 coordinates LORRY's global IIN, including a DT-dedicated network and service offerings, thanks to intelligent products and digital platforms. Site B1 dramatically improves its chassis development and production process for the IIN using internal and innovation platforms. Site D1 leads the Brazilian IIN coordinating the manufacturing and project services besides offering digitally enabled platforms. Site D2, the technological reference for capacitors in case D, develops innovation and internal platforms to improve functional integration and the plant's productivity. Site E1 pivoted from the telecom industry to digital services by discontinuing the former operations, restructuring to become a services provider, and incorporating capabilities through M&As. Site G1 uses CPS to improve productivity and digital platforms to integrate the entire logistics chain of its IIN. The examples above expose a variety of trajectories for Lead sites. In common, they all gain relevance in their respective IINs, reinforcing their Lead roles.

On the other hand, Lead Sites may downgrade, as we observed in two instances. The first one was Site F1, which lost relevance due to a downgrade in its locational factor. The second one is Site B2, recently incorporated into the Latin American IIN. In both cases, the loss of strategic importance caused the downgrade of the Lead Sites. Being unique situations in our sampling not causally related to DT, we will not analyze the Lead Sites downgrade in more detail here. We will return to them in the next Chapter.

Regarding the Contributor role, Sites A2, C2, C3, C4, C5, E2, and G2 actively participate in DT, enhancing their capabilities to contribute by leading several IIN-level initiatives using the DT journey of IIN Integration, as detailed in Appendix D. Depending on the level of activities captured, Contributor sites may also upgrade to the Lead role. The separate R&D and production operations co-located in C1 integrated their functions, captured activities with the control towers, and assumed a Lead role in the IIN. We call this new integrated operation C1** to differentiate it from the former manufacturing plant. Similarly, Site F2 concentrated production, captured further responsibilities, and incorporated the R&D function from Site F1, upgrading from a Contributor to a Lead role. Although not fully integrated yet, the framework predicts that the co-located Sites A2, A3, and A4 may turn into a single Lead site in the future, following the same path as Site C1**. We depict it in brackets as Site (A2**) in Figure 12.

Server sites may present two evolutionary paths. DT provides the opportunity of upgrading to the Contributor role by capturing higher-order activities such as leading DT projects associated with the IIN Integration DT Journey. Sites C6, C7, C8, and C9 exemplify this path. The other path is to specialize in specific products, niches, or services in a specific market, like sites A6/B6. They continue to hold a role that resembles the Server role, still focused on serving a specific market, now better integrated into their IINs thanks to internal digital platforms. Remote management of some activities like planning and logistics may remove some of these sites' capabilities. The industrial plants complex D3*, an example of Server Sites' cluster, has not yet undergone significant DT. Therefore, the analysis predicts that the complex may still evolve into one of the paths we described.

Source factories in the model from Ferdows distinguish from Offshore factories because they aggregate activities like “procurement (including the selection of suppliers), production planning, process changes, outbound logistics, and product customization-redesign” (FERDOWS, 1997 p.76). To do that, they require expensive managers that partially offset the low-cost advantage of Offshore factories but compensate in higher autonomy and flexibility (FERDOWS, 1997). With DT, the type of activity that characterizes the Source factory, like planning and logistics, moves abroad to other sites within the IIN as part of the IIN Integration DT Journey. Sites A5 and G4, and the three Offshore Sites B5* evidence the loss of capabilities at Source sites. The differences between Source and Offshore sites vanish, and the site roles evolve into a single digital era plant role. Nevertheless, both Source and Offshore Sites gain new digital capabilities to operate the internal digital platforms improving their integration to their IINs as part of their DT journey of IIN Integration. Besides, Sites A5 and G4 retain higher-order capabilities like process development that Offshore Sites like B5* may gain with the higher integration of the IIN.

So far, we have covered the factory roles from Ferdows’ typology. Nevertheless, there are still relevant IIN operations that Ferdows’ model does not consider. Sometimes, the IIN decides to build specific sites to capture IIN-level activities using CPS and internal digital platforms instead of concentrating them at Lead or Contributor Sites. Sites B3, a consolidation center, and C12, a control tower, lack production but manage IIN-level production activities like procurement, production planning, logistics, maintenance, and quality. The responsibility scope varies from a local cluster, like

C1**, C12, and G1, to regional, like sites A2, C1**, and F2, and global reach, like in case B. This type of control site derives from the internal platforms created in the DT journey of IIN Integration. The same site may retain different responsibility levels for different systems, like site C1** with a local cluster scope for quality and maintenance and regional scope for planning and logistics.

Distribution Centers were not part of Ferdows' model. Internal digital platforms and CPS integrate these operations into the IIN to improve the entire chain's productivity and product delivery. Sites A7/B4, F1, F3, and the DC network G5* are examples of Distribution Centers' integration to IINs. In common, they locate close to markets and aim at providing logistics services to customers. Integration to the IIN allows the optimization of inventories and product delivery improvement to customers at the Distribution Centers and better production planning at the factories. Therefore, the incorporation of Distribution Centers to the IIN follows the IIN integration DT Journey, improving production flows, inventory levels, and customer service.

Ferdows (1997) considers R&D only when collocated with a production factory. The DT journey of IIN Integration approximates the R&D and production functions, even if the R&D center and the factory are separate sites. R&D sites improve their interaction with production sites, thanks to industry and internal digital platforms. If co-located with production sites, DT promotes their integration and upgrade to the Lead role like sites B1, C1**, D1, E1, F2, and G1. The level of integration differs for each case, being more advanced in C1** and F2, where R&D has taken some traditional responsibilities from production such as quality in case C or maintenance in case F. Multifunctional teams, not restricted to R&D and production, work together to develop new products and services. Site F2 leads this tendency with production staff actively supporting R&D. Still, stand-alone R&D centers are present in cases A3, not entirely digitally integrated into the network, and E4*, the companies acquired by DIOCO to gain software and digital platform competencies. The digital services development network in E4* uses internal and industry platforms for a virtual co-location.

4.3.2 Impacts of Life-Cycle DT journey

We did not find examples of sites that fit the Outpost role from Ferdows in our cases. Nevertheless, the innovation ecosystems A9*, C14*, E7*, and F4*, described in the Life-Cycle Integration DT journey, are examples of digital outpost operations. These ecosystems support the R&D centers in developing new products, like in cases C and F, and digital service solutions, like in cases A and E, using digital industry platforms. Innovation ecosystems include various internal and external partners using fast development techniques, as described in Appendix D.

Like outpost factories in Ferdows' model, the innovation ecosystems seek access to competencies and knowledge. Nevertheless, they do not require the presence of production. Another difference is that these ecosystems do more than "collect information" (FERDOWS, 1997 p.76) since they actively develop product prototypes, apps, software, platforms, and digital solutions. These differences confirm the growing relevance of data as a significant factor in manufacturing besides production, as we presented in the introduction of this work.

4.3.3 Impacts of Digitally Enabled Servitization

Contrary to Ferdows factories, centered around production, digital Lead and Contributor sites may coordinate not just production but also service delivery for their IINs using the Digitally Enabled Servitization DT journey, like D1, E1, and E2. Economic digital platforms support the servitization effort. There are also operations to precisely manage the service delivery like site A4 for fleet and logistics optimization and the start-ups in G3* that guide farmers in optimizing CROP's products application. As case D implements intelligent products, the framework forecasts a control center's development like sites A4 and G3*, should the MNE choose to follow a Digitally Enabled Servitization DT journey. Figure 12 represents this hypothetical site as (D4). Service control centers like A4 and G3* manage digital economic platforms for service delivery, while the control centers in the IIN Integration DT Journey manage internal digital platforms. In common, they locate where required capabilities exist to operate the platforms, their primary activity.

The business ecosystems for service delivery require a network of service providers located close to markets. Service centers, like distribution centers, are not part of Ferdows' model. They locate close to markets and support customers' specific needs, like service centers C11* and A8* and training centers A7/B5 and E5. The network of distribution centers G5* and site A7/B4, described under the IIN Integration DT Journey, are other examples of sites that do not make any product but play a fundamental role in the digital era IINs. In common with the service providers, they share the proximity to market as their strategic reason to locate and deliver a service to customers as their primary activity.

4.3.4 Impacts of Relocation

Relocation of production took place since the early stages of DT. Process industries concentrated production of high-volume goods into global plants as seen in cases C and G. I3.0 technologies promoted the automation of continuous and make-&-pack production, enabling high-volume automated plants close to consumer markets.

I4.0 technologies led to higher agile, flexible, and productive production lines. The increased capacity allowed plants to concentrate production from a dispersed network of plants to digitally integrated lead or contributor sites. In case A, site A5 lost the extra-heavy truck production to site A2 whereas in case F, the I4.0 line at Site F2 displaced production from sites F1 and F2. Although an isolated case, F3 is emblematic. The DT journey of Relocation transferred all production from that site into Site F1. However, instead of shutting down operations, it turned into a distribution and services center to the local market as part of the DT journey of Servitization in case F. This move may indicate an alternative to shutting down for sites that lost production. In this case, F3 will evolve into a role of service delivery to local customers.

Another type of production relocation takes place with customization. Specialized plants that make customized products for niche markets appear in case C with a series of M&As, C10*. Other server sites focus on specific products or markets like Site A6/B6 in cases A and B, and eventually the industry cluster D3*. These sites resemble Server Sites from Ferdows without planning and logistics capabilities but enjoying greater integration with their IINs.

The academic literature considers 3-D printing and additive technologies as the drivers for production relocation in the digital era. (BARBIERI et al., 2018; BRENNAN et al., 2015; STRANGE; ZUCHELLA, 2017. However, the field research contradicts the literature since no case presents additive technologies in production. One explanation for this absence is that the 3-D printing technology is appropriate for specific sectors like apparel (LUND et al., 2019). On the other hand, there is evidence of 3-D printing as an essential tool for R&D fast prototyping and spare parts inventory reduction in cases A, B, C, D, F, and G.

4.3.5 Proposing the Digitally Enabled Multinational Inner Network (DEMIN)

Table 13 summarizes the previous Sections analysis, displaying how each DT journey reshaped and created Site roles in ways that Ferdows' model would not predict. Using Table 13 as a reference, we propose expanding the traditional framework by introducing the Digitally Enabled Multinational Inner Network (DEMIN).

Lead, Contributor, and Outpost are the three roles that evolve, maintaining their names. The core of the LEAD and CONTRIBUTOR roles remains the same, with important additions like higher integration with other functions, management of internal digital platforms to coordinate IIN activities, and higher agility to respond to the IIN's and market's demands. Lead and Contributor sites may take part in all DT journeys, improving their productivity with IIN Integration, speeding the development and deployment of new products and services with Life-Cycle Integration, assuming the coordination of digital services with Digitally Enabled Servitization, or capturing production capacity with Relocation. Contributor Sites can upgrade to Lead if assuming global responsibilities in their IINs. On the other hand, Lead and Contributor Sites may lose the coordination of some activities transferred to other Sites in the IIN. Therefore, we maintain these roles in the DEMIN model, updating their names to Digitally Enabled Lead – DE Lead – and Digitally Enabled Contributor – DE Contributor.

DE LEAD sites are global hubs of knowledge that determine the IIN's objectives, strategy, products, services, and processes. When DT promotes the technological and organizational changes to the IIN, the Lead sites may transfer some of their lower-level management activities to Control Centers, releasing resources to focus on higher-order activities. Besides, the higher integration of the IINs increases the Lead sites' agility and flexibility to coordinate the network. Contributor Plants may upgrade to the DE Lead role if they aggregate enough capabilities to take global MNE responsibilities like a leadership role in specific production systems for the firm. Cases C, F, and eventually A show examples of co-located sites that upgrade by integrating R&D and production activities.

Table 13 - Impact of DT on plant roles

DT STRATEGY	DT JOURNEY	IMPACTED ROLES
Integration	IIN Integration	*Reinforced:* Lead, Contributor *Upgraded:* Server to Contributor, Contributor to Lead *Created:* Control Center (IIN activities), Customer-oriented site (Distribution Center) *Evolved:* Source and Offshore into Production Center *Incorporated:* R&D Center
	Life-Cycle Integration	*Reinforced or upgraded:* Lead, Contributor, R&D Center *Changed:* Outpost without production (innovation ecosystem)
Servitization	Digitally Enabled Servitization	*Reinforced:* Lead, Contributor *Created:* Control Center (Product-service system), Customer-oriented site (Service Center, Training Center)
Relocation	Relocation	*Loss of production function:* Source, Offshore, Server *Captures production:* Lead, Contributor *Transformed:* Server to Customer-oriented site (Customization Center)

Source: Author

DE CONTRIBUTOR Plants in the DEMIN model have a similar role as in Ferdows' but enjoy higher integration to the IIN. Some lower-level management activities move to the Control Center, releasing the Contributor Site to focus on higher-order activities. Contributor Plants enjoy high connectivity to other DEMIN plants, supporting or leading products, processes, and systems development. The proximity to the market is their main strategic reason to locate. They use this advantage to collect tacit data about the customers and the market they serve. Focusing on higher-order activities, DE Contributor Plants also require digital skills and knowledge to fulfill their activities.

The third role that maintains the original name is the Outpost. As we analyzed in Section 5.3.2, the Outpost role evolved from an information collection center to an active participant in the innovation ecosystem. We update the Outpost to DE OUTPOST to keep the similarities and reflect the two roles' changes. The strategic reason to locate DE Outposts is access to knowledge and capabilities, while its activities support the innovation ecosystem. DE Outposts communicate in real-time with the other units of the IIN through digital platforms. All units that form innovation ecosystems can be part of the IIN as outposts, including third-party firms.

The other three plant roles in Ferdows' model evolve in different ways. As we discuss in Section 5.3.1, the need to balancing low-cost and remote management for Offshore Plants and high-cost local management for Source Sites disappears, leading the Offshore and Source roles to merge into a single role that we call PRODUCTION CENTER. Production Centers have access to low-cost production as their main strategic reason to locate. The focus of Production Centers is production. Although they lose some of their management activities, they still retain higher-order activities like process development and gain capabilities to operate the digital platforms that connect them to the IIN. Nevertheless, Source and Offshore sites also risk losing part or all their production capacity, as discussed under Section 5.3.4.

The last role in Ferdows' typology is the Server role. The Server Plant from Ferdows may follow two different paths. High volume Server Plants upgrade to become Contributor Plants since it is unlikely that sites with so much skill, data, and knowledge would downgrade. Smaller volume Server Plants may specialize and become Customization Centers that are highly agile and flexible operations that we name under the broader Customer-Oriented Site role, described in the next paragraph.

CUSTOMER-ORIENTED SITES intend to meet internal or external customers' requirements. These sites' proximity to the market is their main strategic reason to locate because it confers them the needed agility and flexibility. They also focus on specific activities. Different operations fall under this classification. The first one intends to meet specific customer needs by manufacturing niche or customized products. These customization centers may evolve from a Server Site or enter the IIN through an M&A or JV. The second type of site aims at delivering services to a specific market, typically through a network of proprietary or third-party lightweight service centers as part of the Digitally Enabled Servitization DT Journey. Networks of distribution centers integrated to the manufacturing sites respond for agile product delivery to clients and customers. Other operations like training centers or testbeds provide capacitation to internal and external partners of the IIN. In common with Ferdows' Server factories, these sites serve a specific market, but they may specialize in different activities such as production, distribution, service delivery, or training. Proximity to customers also allows these units to contribute with the IIN in improving products, systems, and the quality of services provided.

In addition to our field research, we provide additional examples of Customer-Oriented Sites, including the use of 3-D printing technologies that we did not observe in the field research. The “store factory” is a small customization center from Adidas, the sports apparel firm, located in shopping malls. There, consumers can go in, design their apparel, have their measures taken with the support of a store employee, have the piece made in a few hours on the spot, and then take it right away (WIENER, 2017). Nike reshored operations in 2013, and Adidas followed in 2017 by opening a new plant in Ansbach, Germany, and later a second one in the US. Adidas coined the concept of a “speed factory” to describe their new plants using technologies such as 3-D printing, collaborative robots, and automated systems to manufacture their customized products (EUROFOUND, n.d.; GREEN, 2016; LUND et al., 2019; WIENER, 2017). These reshoring operations moved production away from low-cost locations and closer to the markets, creating customization sites that fit the Customer-Oriented Site role. DT technologies provided the necessary productivity change to offset the cost of producing at cheaper but farther away locations.

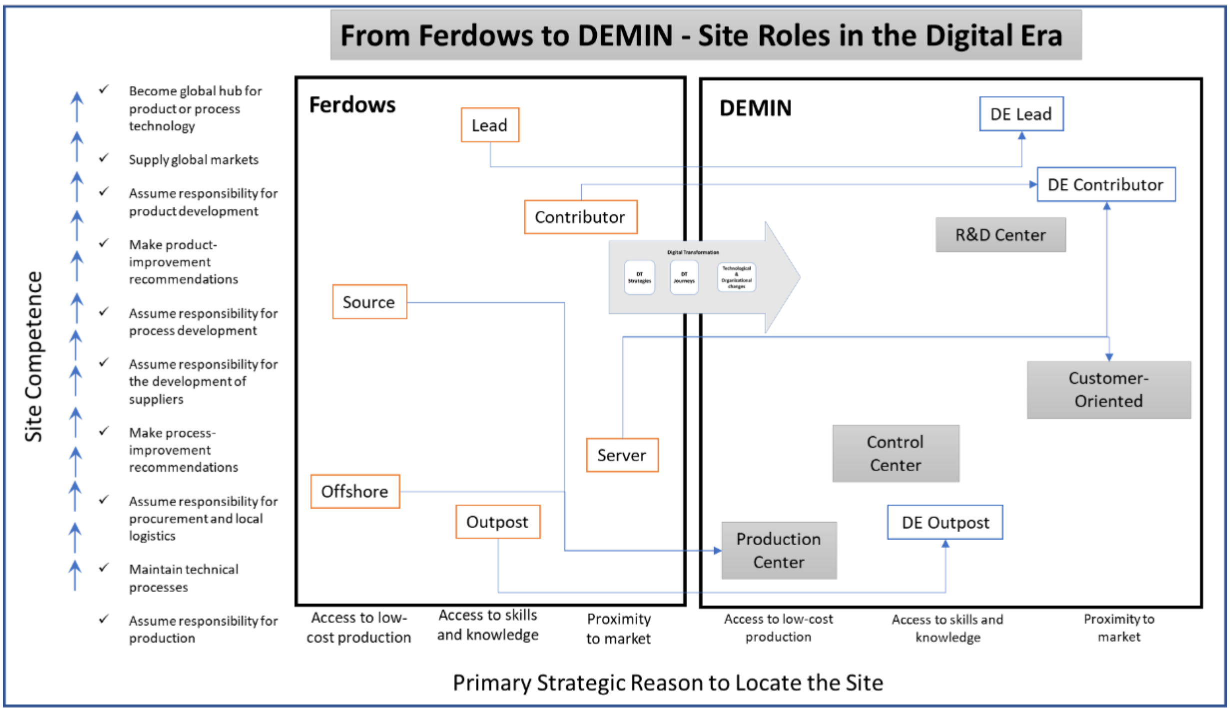
The IIN integration and the Digitally Enabled Servitization DT journeys create operations with different objectives but similar roles. CONTROL CENTERS have access to knowledge and capabilities as their strategic reason to locate. Control Centers in manufacturing have real-time visibility of material flows, inventories, and capacities for the IIN. They optimize the procurement, production, quality, maintenance, planning, scheduling, and logistics management activities for the network. In services, the use of CPSs allows Control Centers to monitor the equipment or service in the field, anticipate service needs, and manage the Lightweight Service Centers' network activities using the internal digital platform of the IIN. Control Centers also manage corporate administrative systems such as Human Resources, Finance, or ICT services, providing standard systems across the IIN. Ferdows’ model did not consider Control Centers' existence because, before the digital era, the necessary technologies were not yet commercially available, so that the execution of the activities mentioned above took place at the site level. Besides, production and services were two separate areas of research.

Besides the evidence collected in our cases, the business literature also provides examples of Control Centers for internal platform coordination or service management that complement the evidence collected in the field. In manufacturing, traditional firms like Bayer, Hewlett Packard, Procter & Gamble, and Roche decided to create Regional corporate service centers in countries like Costa Rica for America, Poland for Europe, and Singapore for Asia (ALVARADO, 2018; CINDE, 2018, n.d.; COSMETICS TECHNOLOGY, 2014; P&G, 2010; P&G POLAND, n.d.; SENTANCE, 2018). Considering the Digitally Enabled Servitization DT journey, Rolls Royce has a data center in the UK that monitors thousands of aircraft engines' operations worldwide in real-time (MARKETING DERBY, 2017). Similarly, Boeing keeps an around-the-clock monitoring center in Everett, Washington, US, to track the global 787 Dreamliner fleet (BOEING, n.d.).

R&D CENTERS are not considered in Ferdows' model unless they are part of a Lead or Contributor factory. The IIN and Life-Cycle Integration DT journeys include autonomous R&D centers as active IIN operations even if not co-located with production sites. R&D centers coordinate industry platforms that integrate innovation ecosystems. Internal platforms allow R&D to speed the introduction of new products, processes, and services across the IIN.

The higher integration of R&D with other functions across the life-cycle dimension of the RAMI4.0 model (ADOLPHS et al., 2015) justifies the inclusion of the R&D Center to the DEMIN model. Its strategic reason to locate is the availability of specific knowledge and capabilities. Proximity to strategic markets is a secondary determinant for the location of these centers. Their activities are to research and develop products, services, processes, and systems for the IIN. There is a tendency to co-locate Regional R&D Centers with manufacturing plants as proximity fosters broader inter-function collaboration (BRENNAN et al., 2015), but they can still operate as stand-alone units, though now connected to manufacturing sites through CPSs. Regional R&D Centers manage digital industry platforms to broaden their innovation ecosystems by allowing many collaborators to join it from inside and outside the IIN.

Figure 13 - From Ferdows typology towards the DEMIN model through DT



Source: author

The business literature also provides further examples of how firms manage their R&D activities in the DT era. P&G recently opened Global and Regional Innovation Centers in the US for North America, Brazil for Latin America, Warshaw for Europe, and Singapore for Asia, some co-located with production Sites, others as stand-alone operations (CARNEVALLI, 2019; COOLIDGE, 2019; P&G POLAND, n.d.; WILLIAMS, 2017). P&G's digital innovation center in Singapore intends to research and develop new digital solutions for the company (WILLIAMS, 2017). IBM announced a new AI R&D center in Brazil that will join one already existing in India and its other centers located in the US (BRIGATTO, 2019). GE has specialized R&D centers in the US, India, China, Germany, and Brazil, fostering local innovation (GE, 2014). For example, GE's Brazil R&D center, located in Rio de Janeiro, works closely with Petrobrás, the oil Brazilian MNE, with an expected "focus on developing advanced subsea oil and gas technology" (GE, 2014). This last example supports the statement that MNEs also locate R&D centers close to strategic clients or markets to meet their demands. Figure 13 displays the evolution from Ferdows' framework to DEMIN's. Table 14 summarizes the above discussion about plant roles.

Table 14 - Comparing Ferdows and DEMIN

Strategic Reason to Locate	FERDOWS	DEMIN	COMPARISON AND CHARACTERISTICS
Low-Cost Production	Offshore	Production Center	The Production Center is remotely coordinated by the Coordination Center in real-time, eliminating the dilemma of having delayed remote coordination (offshores) or in-site high-cost resources (servers)
	Server		
Access to Knowledge and Capabilities	Outpost	DE Outpost	The Outpost of the DEMIN model does not require in-site manufacturing, as it is connected in real-time to the rest of the network
		Control Center	A new type of Site that manages production or service management activities for the IIN.
		Regional R&D Center	Included in the DEMIN model due to the higher functional integration of R&D and production
	Lead	DE Lead	Lead in the DEMIN model transfers some lower-order management activities to the Coordination Center and focuses on higher-order activities
Proximity to Market	Contributor	DE Contributor	Contributors in the DEMIN model lose lower-order management activities related to production, but gain relevance as a link to the market, contributing to the development of systems, processes, products
	Source		Source Plants become Contributor Plants or Customization Centers depending on their original characteristics
		Customer-oriented Site	A new type of Site, agile, flexible to provide customized goods and services according to customers' requirements. It includes customization, distribution, service delivery, and training centers.

Source: The Author

5 CONCLUSION

In this exploratory research, we intended to understand how and why DT reshapes the MNE’s international operations, plant roles, and IINs’ configuration and coordination. To meet our main objective, we designed three specific objectives to guide our research. The first one was to understand what DT strategies and journeys exist and how MNEs implement them. The second specific objective was to update both Shi and Gregory’s and Ferdows’ models on network types and plant roles. The third specific objective was to understand how DT would impact the MNEs’ Brazilian operations.

We developed our conceptual framework using the review of the literature. Our starting points were the seminal IOM models from Shi and Gregory (1998) for the IIN level and Ferdows (1997) for plant roles. We used Vial (2019) and other authors to build our working definition of DT and describe its technological and organizational dimensions. Our next step was to review the IOM literature on strategy in general and DT strategy to develop the definition we used in this work. Finally, we analyzed the literature's scarce intersection on IOM and DT in Section 2.8. We identified three DT strategies: Integration, Servitization, and Relocation. We also extracted four DT journeys: IIN Integration, Life-Cycle Integration, Digitally Enabled Servitization, and Relocation. Closing the literature review, in Section 2.9, we introduced the conceptual framework, depicted in Figure 6, and summarized in Table 7.

Chapter 3 presented the study's research project following the guidelines from Cauchick Miguel et al. (2010) and Karlsson (2016). The method we selected was case research with an abductive qualitative approach (CAUCHICK MIGUEL; SOUZA, 2012; DUBOIS; GADDE, 2002; VOSS; JOHNSON; GODSELL, 2015, 2016; VOSS, TSIKRIKTSIS; FROHLICH, 2002; YIN, 2015). We adopted the evolutionary process research method as we studied a transformation phenomenon, DT, with a substantive worldview, where research subjects are entities like the IIN and the site, not the DT process itself (ABDALLAH; LUSIANI; LANGLEY, 2019; GEHMAN et al., 2018; LANGLEY et al., 2013). Our empirical evidence stemmed from seven cases of MNEs operating in Brazil, an emerging market, that we assessed through interviews with DT stakeholders and secondary source reviews. The sampling logic followed Langley et al. (2013) for longitudinal process studies, and we developed the sampling criteria from similar IOM studies like Baines et al. (2020); Blomqvist and Turkulainen (2019), Cheng, Farooq, and Johansen (2011), and Feldmann et al. (2013). The research protocol followed guidelines from Yin (2015).

We executed the field research following the research protocol from Appendix A. The abductive nature of our research led to a series of interview cycles using focused questionnaires like the example in Appendix B. Coding, of which Appendix C is a sample, followed the process described in Chapter 3.Appendix D displays the field research findings using the conceptual framework as a backbone to build the narration. Each case provided evidence of the DT strategies employed, the DT journeys taken, the technological and organizational changes implemented, and the IIN's and site levels' consequences.

In Chapter 4, we analyzed our research findings considering our main objectives. Section 4.1 discussed the conceptual framework's internal validity and its constructs by providing evidence that each DT strategy leads to DT journeys that will provoke technological and organizational changes, as we summarized in Table 12. In Section 4.2, we analyzed DT's implications at the IIN level, proposing that DT reshapes the IIN coordination in a manner that is not part of the model from Shi and Gregory (1998), the network coordination. In Section 4.3, we analyzed DT's implications at the site level using the model from Ferdows (1997) and proposed the DEMIN model that updates, transforms, and expands the traditional model with site roles of the IIN after the DT. We achieved the third specific objective by selecting the subsidiaries of one local and several foreign MNEs operating in Brazil, an emerging market. The following section presents our work's theoretical and practical implications and its limitations and possibilities for future research.

5.1 IMPLICATIONS TO THEORY

In Section 1.6 from the Introduction, we built our intended contributions following the essential elements of theory from Whetten (1989). We added a “how,” the DT process, to justify the evolution of the “whats,” the frameworks from Shi and Gregory (1998) at the IIN level, and Ferdows (1997) at the site level, as we depicted in Figures 9 and 10 in Section 3.3.1. Based on the literature review, we developed our conceptual framework shown in Figure 6 in Section 2.9, composed of a sequence of events where new digital technologies trigger DT strategies that launch the DT journeys, promoting technological and organizational changes, leading to modifications in the configuration of the IIN and the role of its sites. Section 5.1 validated the conceptual framework. Sections 5.2 and 5.3 provided the analysis at the network and plant levels, respectively, offering the “why” of Whetten’s proposal for a good theory, or the explanation of why DT reshapes the IIN’s configuration and the role of its plants, both evolving in novel ways that the traditional models cannot explain. The boundaries of the framework were the IIN and its sites (“who”), Brazil as an emerging market (“where”), and DT’s implementation period representing the longitudinal dimension (“when”).

The elements we described in this Section so far comply with the requirements of a new theory, according to Whetten (1989). We also mentioned the originality and utility dimensions that characterize theoretical contributions, according to Corley and Gioia (2011). The originality of this work is, at the same time, incremental and revelatory. It is incremental in the sense that we expand the seminal models from IOM. It is revelatory as we introduce different DT journeys to explain the several forms that will generate the changes required to transform IINs and sites from traditional to digital entities. The utility of this work is both scientific and practical since it expands theoretical models, as we will detail in the remainder of this Section, and at the same time is based on empirical evidence, therefore serving as a framework for MNEs to plan and execute their DT processes as we detail in Section 5.2. Once we explained how this study complies with the essential elements of a theory from Whetten (1989) and the characteristics of a theoretical contribution according to Corley and Gioia (2011), we detail the theoretical contributions in the next paragraphs.

Our first intended theoretical contribution was to unveil the mechanisms that explain how DT reshapes the configuration of IINs and their plants' roles. To achieve this contribution, we defined the constructs of MNE, IIN, IIN configuration, IIN coordination, site role, DT, DT strategy, technological and organizational changes, using the literature review as a supporting element to build the definitions. After our first interviews, we incorporated the notion of DT journey to our analytical framework, in line with the abductive approach where the researcher transits between the theoretical and empirical worlds to develop a theory (DUBOIS; GADDE; 2002). The DT journeys materialize DT strategies promoting the technological and organizational changes that will reshape the configuration of the IIN and the role of its sites. We listed four DT journeys and their implications for MNEs. The empirical evidence from the cases in this study provided internal validation to the DT journeys, their implications in the form of technological and organizational changes, and the IIN- and site-level implications, as presented in Chapter 4.

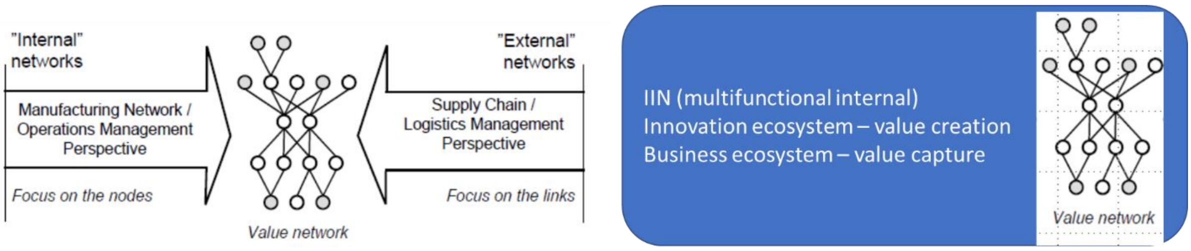
Extending the IOM models from the late 1990s by introducing DT as a reshaping factor is the second implication to theory from our work. In Whetten's terms, we build a new box or a new "what," the DT process, that expands the classical models and provides the reason or "why" they evolve as they do. At the IIN level, Shi and Gregory (1998) proposed two modes of coordination, multi-domestic and global. In Section 5.2, we discussed how DT integrates the units of an IIN, allowing them to propose and jointly decide what DT projects will proceed and who will lead each one. This type of coordination does not fit the model from Shi and Gregory. It is not the global type, where the leader centralizes all coordination with little autonomy for the other network members. Nor is it the multi-domestic type, where each site is autonomous and takes decisions independently from the leader. It is a type of coordination where the units preserve their autonomy while participating in the decision-making process at the IIN level. We named it "networked coordination" and proposed a typology for the resulting configurations, the Transnational Integrated and the Regional Integrated networks.

At the Site level, the main theoretical implication is that activities previously executed at each site now occur at the IIN level, thanks to digital technologies introduced with DT. The basic assumption from Ferdows that a unit of the network must have production activities is no longer valid for several reasons. The first one is that digital tools like CPSs and platforms enable production activities to move to the IIN level instead of the traditional plant execution. Control centers manage activities like planning, procurement, logistics, quality, and maintenance. Back in the 1990s, these activities had to take place inside the factory.

Similarly, R&D and logistics integration only occurred if the R&D or Distribution Center co-located with the plant, which is no longer mandatory in the digital era. CPS and digital platforms interlink activities at the IIN level, allowing a single site to monitor, control, and manage them across all IIN sites. Another reason is that the same IIN handles products and services because of the Digitally Enabled Servitization DT journey. In this new setting, firms must consider operations that make products and provide service offerings, something not foreseen in the plant roles from Ferdows. The DEMIN model reflects these new improvements, still maintaining the basic framework from Ferdows.

A critical addition to the DEMIN model is the inclusion of innovation and business ecosystems. There is the potential to unite the internal and external perspectives of the MNE networks described by Rudberg and Olhager (2003). Traditionally, the external perspective would use the value network or supply chain constructs to study the relationships between the MNE and its partners, whereas the internal perspective would make use of the traditional IMN to research manufacturing operations (RUDBERG; OLHAGER, 2003; DEMETER, 2017). The IIN includes the factories and other sites without the production function forming an internal ecosystem to make products and deliver services with unprecedented productivity. The business ecosystems integrate not just the traditional partners from value and supply chains. Other participants like the marketplace from case C or end-users like in cases A, C, E, and F join the ecosystem and improve value capture. Innovation ecosystems include any party that contributes to value creation in the network, expanding the traditional R&D networks, speeding the development and deployment of new products, processes, systems, and services.

Figure 14 - IMN x IIN perspectives



Traditional view – internal vs. external networks (RUDBERG; OLHAGER, 2003)

The DT view – IIN involves internal and external partners
Nodes and links are equally important

Source: adapted from Rudberg and Olhager (2003)

In summary, the implication to theory is that the IIN allows a holistic view of the MNE, not restricted to the production function, to its classical partition between internal (IMN) and external (value chains, supply chains) perspectives to study operations, R&D networks to study the development of new products, and service networks to look at service organizations. The DEMIN model allows a single perspective integrating the internal, industry, and business ecosystems resultant from the DT process in ways that traditional models could not forecast. Figure 14 compares traditional IMN and digital era IIN perspectives. The platform and ecosystem constructs cope with the increasing complexity of the IIN structures, reflecting the impact of DT on the MNEs’ operations.

Another implication to theory from our research's empirical findings is a shift in the relevance of the strategic reasons to locate sites. The proximity to the market provides higher agility to meet ever-increasing customer requirements. Access to knowledge and capabilities becomes more significant than before for IINs to develop and operate digital technologies. In theory, access to low-cost production loses importance because other locations' higher productivity and agility offset the low-cost location advantages. Nevertheless, our cases also told us that even low-cost operations could survive and prosper if they join the DT efforts of the IIN and contribute to improving its value creation and capture.

Our work's last theory implication is about operations in emerging markets. One concern that triggered this research was that DT would turn them into mere production centers, transferring all other capabilities to the HQs of the MNEs. The assumption above finds no confirmation evidence for the MNEs operating in Brazil, where our findings show a different picture. Operations in an emerging market like Brazil can become testbeds for new technologies, information sources and development hubs of local markets' idiosyncrasies, and even global leaders for new technologies. According to our empirical findings, Brazilian operations from MNEs are gaining relevance and upgrading with DT, as explained in Section 5.3. Although our field research provided examples of Brazilian plants' leading role in implementing advanced digital solutions, it also indicated that R&D for disruptive innovations remains in advanced countries. Some examples are the electric and autonomous vehicles in cases A and B, the intelligent products and service platforms in case A, new products in case C, and digital platforms to support services in case E.

5.2 PRACTICAL IMPLICATIONS

Besides the theoretical implications covered in section 5.1, the results from this research suggest practical implications that could support MNEs to design and implement effective DT programs, partners to join the ecosystems, and governments to create appropriate environments to foster conditions to attract MNEs and support their growth in their territories. An important practical implication of this research is that DT is a process that intends to meet a strategic objective for the MNE. A process-centric strategy delivers an increase in productivity, a product-centric strategy speeds the development of products, processes, systems, and services, and a customer-centric strategy intends to improve sales and other business metrics. Implementing a costly DT process for the sake of modernization without a clear strategic objective may represent a risk to the MNE and will not deliver value creation or capture, as we discussed in our literature review.

The conceptual framework and the DEMIN model explain how new digital technologies induce the elaboration of DT strategies, translating into DT journeys that promote changes in the technological and organizational dimensions, reshaping the configuration of the IIN and the role of its plants. The model indicates new ways to manage activities across different departments, providing a holistic customer-oriented view of the firm, aligning objectives that might otherwise conflict with each other, and minimizing the issue of separation and silos that impairs the firms' overall productivity. These research findings may also support MNEs in anticipating what actions they need to take once they design their DT strategy and start their DT journeys.

DT promotes an intra- and inter-functional integration that blurs boundaries, favoring the formation of teams with multifunctional skills to cope with the challenges of the digital era, resolving the quest of silos breaking prevalent in traditional organizations (VEROEF ET AL., 2019; VIAL, 2019). The manufacturing functions like R&D, production, logistics, marketing, sales, and administrative functions and services delivery, traditionally managed as separate departments, find in the concept of the IIN a means for an integrated approach.

For the plants that are part of the IIN, the DEMIN model provides opportunities to upgrade in the network through better internal functional integration, the capture of production activities for the entire network, the global leadership of DT initiatives or R&D efforts, or the specialization in a niche, product, or service activity. It is also a warning sign for sites about the consequences of ignoring DT. Our field research also demonstrates that subsidiaries operating in emerging markets like Brazil have a significant role in DT as testbeds, innovation hubs, or market-knowledge collectors. Contrary to our initial concern, our cases indicate an increasing relevance of Brazilian operations in their respective local, regional, and global IINs.

The DT process requires more than an internal firm view, as ecosystems supported by digital platforms allow external players to interfere inside the MNEs' operations, providing valuable data to feed the systems that improve customer satisfaction, product and service development, and productivity. For the firms, fostering innovation and business ecosystems is vital for building competitiveness and gathering value creation and capture. For governments, this research suggests that promoting such ecosystems and providing firms' technical capabilities may improve their countries' competitiveness to attract more business to their territories.

5.3 LIMITATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

Despite the contributions highlighted in the previous sections, this research has its limitations. The first one is that DT is a complex, evolving process. Most of our informants mentioned that they do not know its endpoint. Our field research captured the evolutionary path until the moment of the interviews and some insights of future possibilities, some of which may never materialize. Future research may clarify if DT will result in more implications than we could observe in this work.

By selecting cases from different sectors, we intended to compare them and extract common developments to their IINs and plants. Still, the findings that surfaced may be specific to our sampled firms and not represent their respective industries. More research is needed to increase the generalization power of this study.

Except for one Brazilian MNE, all other cases involve European MNEs acting in the Brazilian market, potentially biasing the research's findings. One path for further research is replicating the study using MNEs from other origins like Latin and North American or Asian. Another path is to analyze subsidiaries from the same MNEs operating in other markets, such as the other countries from the BRICS (China, India, Russia, and South Africa), emerging markets like Mexico, Turkey, South-Eastern Asian markets, or developed markets like the US, the EU, Japan, and Korea. Expanding research beyond Brazil may confirm or expand the findings of our field research.

When we discussed the IIN level implications, we were able to identify a new mode of coordination. The cases we evaluated had multi-domestic coordination and evolved into the networked coordination mode. We theorized that IINs with global coordination would also evolve to network coordination but lack evidence of this evolutionary path. Further studies may provide more insights to update the network-level implications.

Another limitation of our study is that most of our informants were DT leaders in Brazil's management or direction positions. This situation might present a bias towards the perspective of local DT leaders. We compensated for this bias by searching for secondary sources of information that supported the informants' comments. However, diversifying the background of informants in future studies may provide a broader picture of DT. Interviewing DT leaders abroad, local executives, functional representatives, and ecosystem partners could provide a more colorful picture considering these professionals' perspectives.

Being an emergent topic, DT in MNEs offers multiple possibilities for future research besides the ones we already mentioned in the previous paragraphs. One of such possibilities is to look at this research from a different perspective. We adopted an evolutionary process approach because we looked for the consequences to the configuration of IINs and their plants' roles. We identified a sequence of events that are part of this process, in line with Vial's model (2019), and used it to build several evolutionary paths for IINs. We consider that further analysis using a processual view (ABDALLA; LUSIANI; LANGLEY, 2019) should identify the DT parallel sub-steps, enhancing its comprehension, a path Baines et al. (2020) used to study the servitization transformation process. Another possibility is to deepen the investigation on specific characteristics of the MNEs that may affect the options they take when undergoing DT. For example, our results suggest that small operations execute functional integration faster than larger ones. Cases B and F, smaller operations, achieved more integration than their larger counterparts in this study.

Another area for further research is the relationship between strategic choices with product type, manufacturing process, or customers' profile. The last opportunity area for investigation is the differentiation between the business and innovation ecosystems. For products, two cases suggested different ecosystems. For service offerings, the innovation and business ecosystems seem to blend, forming a single ecosystem. These are all areas of further investigation in future research.

COVID19 had a substantial impact on the digitalization of the world. Many firms reported accelerating their DT journeys to ensure their employees' safety and sustain their operations. The impact of this unique phenomenon on DT and IOM is an area for current and future research.

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APPENDIX A – Research protocol

Background

This appendix presents the research protocol for the case studies mentioned in Section 3 – Methodology. We developed the protocol according to the guidance in Yin (2015) and the research protocols from Facin (2017) and Junior (2017) as part of the qualification for the doctorate in Production Engineering and Operations Management at the University of São Paulo in August 2019. Academics and practitioners reviewed the protocol and questionnaire for validation purposes. During the first introductory interviews, answers indicating the notion of a "digital journey" led us to review the research and the protocol to include digital transformation (DT), DT strategy, and DT journey constructs into the analytical framework. DT replaced Industry 4.0 and the digital maturity index from the initial framework. We adjusted the questionnaire to cope with the changes and incorporate the processual approach into the research. This protocol is the result of this review process, in line with the research's abductive nature. Appendix B provides further information about the evolution of this protocol.

A. General view of the case study and objective of this protocol

a. Mission and targets

This protocol intends to organize the case study about DT's impacts on each subsidiary's role and the configuration of the inner international networks (IINs) of Multinational Enterprises (MNEs). The study supports the doctorate thesis presented at the Production Engineering Department of the *Escola Politécnica da Universidade de São Paulo.*

b. Research Question

"Why and how does DT rearrange the configuration of the IIN and the roles of its plants?"

c. Critical considerations for the theoretical structure of the case study

Based on the literature review on Operations Management from Chapter 2, we present the conceptual framework with its constructs and research elements:

*Inner International Network (IIN) is "*a coordinated aggregation (network) of intra-firm plants/factories located in different places" (CHENG, FAROOQ; JOHANSEN, 2015, p.393).

Manufacturing includes production, service delivery, product and process development, marketing, sales, and administrative functions, according to Fleury and Fleury (2012) and Rugman, Verbeke, and Yuan (2011). The production activities split into operational like the operation of a warehouse or production line and system management like planning, procurement, and operations management, as defined by Shi and Gregory (1998). In this context, a site could be a factory, a distribution center, a research and development (R&D) center, a services delivery center, an operations control center, among others.

The *strategic reason to locate* each operation, determined according to the environment where the site will locate, is the first factor that characterizes its role, while the collection of activities executed at each operation is the second factor that determines the role of the site (FERDOWS, 1997; VEREECKE; VAN DIERDONCK, 2002).
The IIN's configuration or its geographical dispersion of the sites, local, regional, multinational, or global, is the first factor determining the IIN network type. The other factor is the coordination of the IIN, which can be multi-domestic, where each site has the autonomy to organize itself,

or global, where a lead site coordinates the network and the sites have little autonomy (SHI; GREGORY, 1998).

Industry 4.0 (I4.0) – a collective term for technologies and concepts from the value chain organization. In the plants, *Cyber-Physical Systems (CPS)* create a virtual copy of the physical world and make decentralized decisions. *Digital Platforms* allow the CPS to cooperate, communicate among themselves and with human beings in real-time, internally to the IIN and externally with *innovation ecosystems* for value creation and *business ecosystems* for value capture (DE VASCONCELOS et al., 2018; GAWER, 2014; HERMANN; PENTEK; OTTO, 2015; TSUJIMOTO, 2018). Maturity models intend to measure the technological and organizational dimensions of Industry 4.0, but they have limitations (CULOT et al., 2020).

Digital Transformation (DT) is *a process that aims to improve the MNE by triggering significant changes to its IIN configuration and plant roles through combinations of digital technologies. New digital technologies* create *disruptions* at the society and industry levels, triggering *strategic responses* by the firms aiming to adopt these technologies to *change their value creation paths*; DT will require *technological* and *organizational changes*.

Cyber-Physical Systems (CPS) are tools for connecting the physical and digital domains through computer networks that monitor and control the physical processes, involving them in control loops where the physical systems alter the digital systems and vice-versa (HERMANN; PENTEK; OTTO, 2015; LEE; BAGHERI; KAO, 2015; LU, 2017; MONOSTORI et al., 2016; RODRIGUES; DE JESUS; SCHÜTZER, 2016).

Digital Platforms and Ecosystems – each plant in the IIN belongs and interacts with different ecosystems, directly or through Digital Platforms. Each plant interacts within the IIN using *internal platforms*, with its *business ecosystem through economic platforms*, and with its *innovation ecosystem* through *industry platforms*. These interactions influence the development of competencies related to the plant's functions and its capability to create and capture value for the MNE *(DE VASCONCELOS GOMES et al., 2018; GAWER, 2014; KETOKIVI et al., 2017; TSUJIMOTO et al., 2018).*

DT Strategies - "*digital transformation strategy is a plan to conduct the firm through the process that aims to improve the MNE by triggering significant changes to its IIN configuration and plant roles through combinations of digital technologies." DT strategies can be process-centric, aiming at productivity improvement, product-centric focused on increasing development, and business-centric, targeting to improve value capture. There are three types of DT strategies*: *1) integration, 2) servitization, and 3) relocation.*

DT Journeys – There is no academic definition for the DT journey. We use the term to define the paths firms will take to implement different DT strategies using DT trends. We present the DT journeys in the next topic.

d. Conceptual framework

The conceptual framework suggests that digital technologies like mobiles, CPS, and digital platforms trigger DT strategies that launch DT journeys, resulting in technological and organizational changes. These changes reshape the configuration of the IIN and the roles of its plants. There are four types of DT Journey, depending on the DT strategy:

The DT Journey of IIN INTEGRATION will establish new coordination patterns and mechanisms using CPSs and internal digital platforms, impacting the site management practices and its interrelationships within the IIN to improve the agility, flexibility, and productivity of the IIN.

The DT Journey of LIFE-CYCLE INTEGRATION will incorporate R&D centers and their innovation ecosystems into the IIN regardless of their co-location with production sites, creating coordination mechanisms to reconfigure the IIN and its sites' roles to speed the development of new products, processes, and service offerings.

The DT Journey of DIGITALLY ENABLED SERVITIZATION will favor incorporating digital service offerings into manufacturing firms with a corresponding change in the IIN's configuration and plant roles to improve value capture using business ecosystems.

The DT Journey of RELOCATION will increase the MNE's value capture by relocating production from low-cost locations to agile close-to-market production sites, focused on making customized products using digital technologies, changing the IIN's configuration and its plants' roles.

e. Role of the protocol

The protocol organizes the case study process aiming at understanding how and why DT reshapes the roles of the plants of an IIN by changing the dimensions of the classic IOM frameworks: a) the strategic reason to locate each plant, impacting the geographical dispersion of the IIN; b) the activities executed by each plant and the coordination mode of the IIN. The protocol guides the research to evaluate longitudinal effects at both analysis levels, the IIN, and the site. The protocol also focuses on the research to optimize interaction opportunities in each of the cases selected.

B. Procedures for data collection

This section aims to structure the process to prepare data collection, including the data collection plan and the preparation for fieldwork considering the plant and IIN levels of analysis.

a. Data collection plan

i. Expected type of evidence

In the current processual research, at the plant level, we want to collect data and information that allow comparing the plant's actual role in the IIN before and after the implementation of DT and the DT strategies adopted and journeys employed in the process. The information collected should clarify the motivators, obstacles, and issues faced during the period, highlighting what the traditional models explain and what they cannot explain. Whenever possible, data collected should clarify the role of other plants of the IIN located in Brazil or abroad and the evolution of the configuration of the IIN.
Our expectation in each step is to gather enough evidence to position the site inside Ferdows' and Shi and Gregory's frameworks before and after implementing DT. The analysis should clarify how and why digital technologies and organizational changes modify the plant's role and explain developments beyond the current frameworks' forecasts.

ii. Primary and secondary sources of data

The primary sources of data will be interviews, documents shared by the companies, and site visits. The secondary data sources will be visits to the firms' websites, public reports, business publications, and material available on the internet. Data collection has the following sequence: a) secondary data collection at the website of the firm, annual reports of public companies, an internet search of academic and business publications (e.g., Revista Exame, Jornal Valor, The Economist) for general information purposes; b) semi-structured interviews at plant level with local contacts that possess information about the role of the site in the IIN, its history as well as relevant aspects for the research – target informants are managers involved in the digitalization program of the site; c) plant visits, including non-structured interviews with users of digital systems; d) interviews with other persons that could provide additional relevant information for the study; e) whenever possible, semi-structured interviews with contacts from other subsidiaries of the firm to complement data collected in the previous steps.

iii. Informants profile

For primary contacts to support the research project, we will look for persons in the VP or Director levels, selecting those who demonstrate an interest in sponsoring our research and providing access to their firms.
For data collection, informants should be familiarized with the history of their plants and IINs, especially the evolution of their roles and configurations with the introduction of different digital technologies. Target informants are corporate or site DT leaders, plant and operations managers, and other leaders who could explain how their plants work, how they implemented the DT from both the technological and organizational perspectives, and how this changed the plants' role the configuration of its IIN.

b. Cases selection

The unit of analysis is the subsidiary of the IIN. We prefer to study the IIN over the global value chain or the supply chain because of its higher explaining power of the internal structure of the MNE, according to Rudberg and Olhager (2003).

i. Case selection criteria

We base our case selection criteria on the recommendations from Abdalla, Lusiani, and Langley (2019), Langley et al. (2013), Voss, Johnson, and Godsell (2016), and the selection criteria adopted by Baines et al. (2020), Bloomqvist and Turkulainen (2019), Cheng, Farooq, and Johansen (2011), and Feldmann et al. (2013). The resulting criteria to select cases for our research are:

a. existence of a subsidiary and manufacturing plants operating in Brazil that belong to an IIN,
b. potential to observe different DT processes and
c. firms from different sectors for the same reasons stated by Baines et al. (2020).

ii. Finding potential cases

Using the criteria from item i), we start by identifying manufacturing sectors of interest, grounding our selection in the Standard and Poors' activity list, filtering for sectors with manufacturing activities like a) automobiles, b) automobile components, c) consumer staples, d) industrial equipment, and e) materials sector.
We build a shortlist of potential cases through different techniques like known contacts, participation in association events related to DT, Linkedin networking, and review of academic and business articles about Brazilian MNEs implementing DT. The primary contacts of the listed firms receive an invitation to participate. For those who accept, follow negotiations on data access and confidentiality matters. The firms who pass these activities become the cases of this study.

c. Communicating with potential cases

i. Identification of primary contacts

We identify the primary contacts at the target firms using different sources. They are acquaintances from past interactions, members of the Brazil-German Engineers Association (VDI Brazil) and the professional platform Linkedin, and persons who maintain contact with the Escola Politécnica da Universidade de São Paulo (USP).

ii. Informal communication contact to inform the contacts about the study, the benefits to the firm, and to confirm their interest and availability

We use this step for approaching known contacts. Initially, we organize an informal meeting with potential sponsors of the case or persons that may introduce us to these sponsors. The intent is to present the scope of the study, potential benefits for the participating firms.

iii. Formal communication and invitation to prospective firms

Once there is an indication that the firm is interested in joining the research, we address a formal invite to the firm to join the case research supported by USP. The request informs the research's objectives, benefits for the firm to join the study, and the firm's consent for data collection with interviews, visits, and document reviews. Confidentiality discussions align the limits to share data from the target companies.

iv. Identification of key contacts in the firm

- Facilitators are contacts that may introduce the research team to the primary contacts, for example, colleagues, alumni from the Graduate program at USP.
- Sponsors are C-level, VP-level, or Director-level persons who can open a communication channel with the other contacts, support the research project, and eventually participate in the data collection process.
- Primary Contacts are DT leaders at Management or Director levels that can describe the firm's DT program from the IIN-level or plant-level perspectives, the DT strategies and DT journeys implemented, and the plants' changes, opportunities, and challenges faced, results obtained, and plans. These contacts can also indicate further contacts to support or complete data collection.
- Expert contacts know details of the DT program, the operations, system owners, and system users.

v. Scheduling the interviews and visits

We schedule interviews and site visits according to the availability of the contacts. Preferably, these activities occur at the sites, but interviews using media like Skype or Zoom occur if face-to-face interaction is not possible. *

*Due to the limitations imposed by COVID-19, all interviews in 2020 took place using online tools.

d. Agenda for visits and interviews

i. Data collection planning, including a prework involving secondary data collection, sharing a guide for informants to prepare themselves, requesting specific materials, are some actions taken to prepare each event.
ii. Resources planning like defining the number of researchers to join the visit, commuting to the site, invitations for Skype or Zoom calls, materials for data collection, and authorizations to enter the visited sites.
iii. Contingency plan – some risks in conducting case research are the refusal of primary contacts to promote access to the firms, the lack of access to the informants, the refusal to answer to the questionnaires, availability issues due to unplanned events for researchers or informants, and confidentiality issues that restrict the collection of sensitive data. To avoid or minimize the risks, we set the following contingency course of action: a) alternative list of MNEs that could contribute with similar data to firms that decide not to join the research; b) request to sponsors to provide two or more potential

contacts; c) flexibility in agenda to allow for last-minute schedule changes; d) alternative modes of connectivity in case a face-to-face interview is not possible; e) open questions that allow general answers avoiding the request of sensitive or confidential data.

e. Naming the cases

We designate cases by alphabetical order: Case A, Case B, Case C, etc. If one firm provides access to more than a case, we designate it with a different letter. Names of firms are fictional due to confidentiality issues. The Sites in each case receive the case letter followed by a number. For example, if case B has an IIN with four sites, we name them Site B1, Site B2, Site B3, and Site B4. If a collection of IIN members has a similar characteristic, like the same site role or the belonging to an ecosystem, it will receive a single site identification followed by an asterisk. For example, if case B has an innovation ecosystem, we call it B5*. In case two operations merge into a single site with DT, it will receive a double asterisk, like Site A2**.

i. List of cases

From the initial tentative list containing ten firms, we completed the selection process with five. The others had issues with legal authorizations or agendas to proceed with the process. The list of cases below displays all cases that accepted participating in this research. We selected one firm per sector. In total, we have five participating MNEs, two of which contributing with two cases each.

CASE (origin)	Industry Sector	Size (Turnover and staff)	Contact	Product type Process type
A – LORRY (Europe)	Commercial vehicles	>USD 25 billion >75k employees	DT mgrs.	Vehicle Retailers & fleets
B – BUS (Europe)	Commercial vehicles	>USD 5 billion >20k employees	DT mgr.	Vehicle chassis Final assemblers
C – CONFAST (Europe)	Consumer staples	>USD 50 billion >100k employees	DT director SC director	FMCG Make/pack
D – POWCAP (Europe)	Power&Energy equipment	>USD 25 billion >75k employees	DT mgr Mfg mgr	Power components Modular assembly
E – DIOCO (Europe)	Digital platforms	>USD 10 billion >25k employees	DT director	Digital services Software solutions
F – RING (Brazil)	Automotive components	>USD 100 million	Indl. Dir. Ops/DT mgr	Automobile parts Modular make/pack
G – CROP (US / Europe)	Chemical – agro supplier	>USD 75billion >100k employees	Site DT mgr	Chemicals Continuous chemical

C. Questionnaire for data collection

The questionnaire for data collection has the following sections: a) general information about the MNE and the Brazilian operations; b) respondent identification; c) open question for DT strategies and journeys; e) questions about the evolution of DT from the technological and organizational perspectives; f) questions about the IIN configuration; g) questions about the plant roles. Section 3.3.3 of the primary document explains the rationale for each item of the questionnaire. Data collection happens by taking notes of the interviews, as explained in Section 3.3.4.

A. General questions about the MNE – most information is collected before actual interviews using secondary sources like websites, publications, and reports. The interviews collect eventual missing data.

1. What has been the global volume and trend in the last years?
2. What is the number of employees now and in past years?
3. What business units the MNE possess? How did DT affect the BUs?
4. What are the products and services by BU? How did DT affect them?
5. How many plants are there in the world? How did DT affect them?
6. How many plants are there in Latin America? How did DT affect them?
7. How many operations are there in Brazil? How did DT affect them?
8. What was the evolution of operations in Brazil?
9. Products and services offered in Brazil?
10. Are there global and local DT programs? Describe their scope, intents, and results.

B. Identification of the informant:

1. What is your role in the MNE?
2. How long have you been working for this MNE?
3. What is your role in the DT process of the MNE?

C. DT strategies and DT journeys

1. Please describe the DT program of your company and this site.
2. How did DT change the relationship of the firm with its clients and partners?

D. DT evolution

1. How did digital technologies change operations at Brazilian sites and the entire network of plants?
2. How did the organizational structure of the firm change with DT?
3. How did the firm implement a culture of support to DT?
4. Is there any other thing that you would like to mention about DT in your firm?

E. IIN configuration and coordination

1. How did DT change Brazil's operations, their relations with the rest of the network, and the headquarters?

F. Plant roles

1. Why are the sites of your firm located in Brazil?
2. How did DT change the number of sites and their activities?

D. Guide for reporting each case study

a. Build case summaries after each interview.
b. The interviewers review and align on case summary content.
c. Informants receive the case summaries for confirmation of the data collected.
d. Researchers code each case summary to build the case report.
e. Write each case according to the following sequence:
    - Data sources.
    - Introduction to the case.
    - The MNE and its operations in Brazil.
    - DT strategies and journeys.
    - IIN-level evolution under the framework from Shi and Gregory.
    - Plant-level analysis and evolution under the model from Ferdows.

APPENDIX B – An example of the second-round questionnaire – Case A

BACKGROUND

The initial protocol questionnaire used in the first round of interviews generated data to fill out the first case summaries and improve the conceptual framework. The gaps in the data collected triggered the second round of interviews. We built case-specific questionnaires to address the missing data. In this Appendix, we display an example questionnaire that we used for Case C. Each case had a similar questionnaire to address specific points.

1) Global IIN – how do Brazilian plants interact with other plants or subsidiaries? What type of coordination exists in this network?
2) Niches – how do They work, what is their relevance to CONFAST (are they third parties, JVs, M&As, how do they integrate with traditional sites?)
3) Digital Platforms – how do they work for clients and consumers? Are they local, regional, or global? How do they integrate with Brazilian functions, systems, or control towers?
4) Do the intrapreneurship and start-up initiatives count with digital platforms? How do they work?
5) How were the Scrum and Squad initiatives conceived and implemented? Are they production-specific, or do they include other functions?
6) What is the relevance of the service network to the MNE's business? Is it just a brand display strategy, or is it a strategic business?
7) Confirm each Brazilian plant's role – how do they interact with other sites in Brazil and abroad?
8) How does the MNE intend to reapply the learnings of one subsidiary to the others?
9) How is the coordination in the MNE? Global, Regional, by the subsidiary, by site?
10) Is the autonomy enjoyed by the Brazilian subsidiary specific, or is it found in other subsidiaries too?
11) Please explain in more details the R&D structure of your company

APPENDIX C – Coding diagram

This appendix displays an extract of coding the cases using Gioia's framework. First-order concepts in the first column convert into second-order themes in the second column, the third column's metrics, aggregate dimensions that define the constructs in the last column.

First-order concepts	Second-order themes	Aggregate Dimensions	Constructs
Case A – Br, Ar, LA Case C – Br + LA Case D – Br exports Case F – Br, Ar, LA	Local or Regional	IIN geographic dispersion	IIN configuration
Case A – HQ, Br, Tq Case B – Br, Ar, LA, overseas Case E – HQ, Subsidiaries including Br	Multinational or Global		
Autonomous subsidiaries (A, B, C, D, E) Lack of standardization (A)	Multi domestic	IIN coordination	
Central coordination (F) DT network (A, B, C, E) Projects approved at IIN level, executed at Plant level (A, B) Top-down Bottom-up projects (C)	Global Network?		
Taxes (A, B, G)	Access to low-cost production	Strategic reason to locate a plant	Plant role
Digital, business (A, B, C, D, E, F) Product technology (B, D)	Access to capabilities and knowledge		
Significant market (BRAZIL) (A, B, C, D, E, F, G)	Proximity to Market		
Factories (A, B, C, D, F, G) warranty service(A), authorized workshops (A) Service platforms (A, C, E, G) Brand service (C) Distribution Centers (A, B, C, F, G) Training Centers (A, B, E) Partners, customers, service providers, Business ecosystems (A, C, E, F, G)	Make products or deliver services[1]	Activities	
Control center for service offerings Integration of manufacturing activities (A, B, C, D, E, F Market models (B) Control tower (C) – logistics, planning, process, maintenance, and quality	Management of manufacturing systems and digital platforms[2]		

Process development (A, B, C, D, F)	Develop and improve systems, processes, and products.		
R&D center adapts products to the local market (A, C); local innovation ecosystem: service development (A, E, F) product development (C, F)	Hub for the development of specific important components, products, or processes.		
The pilot of digital techs (A, B, C)	Development and contribution to the company's knowledge.		
HQ develops global product and service platforms (A, E, F) R&D is a global reference (B, F) Regional reference (A, B, C, D, E, G) Control towers (C)	Center of Excellence – partners with the HQ in building strategic competencies		
DT is a Journey (A, B, C, E, F)	Definition of DT as a Journey		
Four-fold productivity improvement (A, B, C, F) Global & Regional Plants (C) Global systems (planning, procurement (B, C, E) Faster development (A, B, C, D, E, F)	Integration	DT Strategy	
Service offerings with economic platforms and apps (A, C, E, G) Digital marketplace (C) Service using the brand (C) Service to increase loyalty (A, F) Service supporting customer product use (A, E, F, G) Intelligent products (A, D-implement) Shift from production to services (E)	Servitization		DT process
Production concentration (A, C, F) M&As for customization (C)	Relocation		
Flexible production, smart automation, digital works support (A, B) Internal digital platforms (A, B, C, D, E, F, G) R&D and production integration (B, C, D, E, F) R&D and production shared responsibilities (C, F) Applied research (A, B, C, D, E, F)	Digital Function Integration	DT Journey	

Planning, Procurement, Logistics integration (DCs) – (A, B, C, E, G)		
Innovation ecosystems (A, C, E, F)	Life-Cycle Integration	
Materials & product development platform (C, F)		
Telematics and fleet management services (A)	Digitally Enabled Servitization	
Apps for drivers (A)		
Reward/loyalty program (A)		
Services use MNEs products (C)		
Digital platforms for PLM (E)		
Customer orientation platforms (A, E, F, G)		
M&A of start-ups and niche companies (C)	Relocation	
I4.0 lines (higher agility) (A, B, F)		
I4.0 line – assembly lines (A, B, F)	CPS	
I3.0 automation– continuous processes (C, G)		
Automated packing line (G)		
Nine digital technologies BCG - (A, B, C, E, F, G)		
IoT, IoS, CC, BDA, AR, AM, CS, AI, Cobots, inteligent badges (A, B, C, E, F,G)		
Vision System, online testing (quality) (A, B, C, F)		
Quality testing automation (D, F)		
Cobots (A, B, C, E, F)		
automated process controls (C)		
Tablets (A, B, C)		
autonomous lift trucks (A, B)		
AR for training and operation (A)		
Interactive human-machine devices (A)		
Man-machine interfaces (B)		Technological Change
Intelligent products, onboard firmware (A, D)		
Monitor, forecast, simulate (A, B, C, D, E, F)		
AGVs (pulled line vs. pushed line concept) (A, B)		
Process set-up time eliminated (A, B)		
Higher flexibility and agility (A, B, C, D, E, F)		
Increased capacity (A, B, F)		
Digital plant design before construction – digital twin (B, E) x I4.0 line construction - digital shadow (A)		
Satellite Imaging (G)		
App development (intrapreneurs, developers, after-sales) (A)	Industry platform	
Data lake digital library (B)		
e-center (B)		

Industry/Economic platform for services (A, E) The industry platform for product development (C, F) Telematics (A) Fleet management (A) Gamification – customer loyalty(A) Regulatory app – customer loyalty (A) Marketplace (C) Industry/Economic platform (E) Product selection &use - Customer loyalty (F, G)	Economic platform	
Production Planning, Production Execution, and logistics platforms (A, B, C, D, E, F, G) lift-truck fleet mgt, (A, B) Global Consolidation Center (procurement) (B, soon A) Life cycle integration (E) Control towers (C) – top-down and bottom-up Machine learning – “quick wins” digital projects, e.g., utilities (steam, energy) optimization(C, G)	Internal platform	
No production, Fast prototyping, spare parts, production devices (A, B, C, E, F)	3-D printing	
AR for training and operation (A, B, C) AR for early life cycle and project design (E, F) AR to support proper installation and servicing (A, F)	Augmented Reality	
Pre-DT Lean (A, B, C, F, G)	Lean manufacturing	Organizational Change
DT leader (A, B, C, D, E, F, G) – ICT supports The matrix structure of DT program leadership (A)	DT leader	
Scheduled review meetings (A, C, E, F)	IIN-level review	
Process development teams (A, B, F) Swarm methodology (B) Multi-functional teams (B, C, E, F) R&D and production responsibilities (C, F)	Cross-functional collaboration	
People pillar (A) Training and capacitation using an external agent (SENAI) (A, B) Intrapreneurship– return 10x higher than traditional projects (A, B, C, F) Tolerance to errors, customer focus, empowerment, (B, G) Elimination of competence silos (E) Lean principles (F)	Cultural adjustment initiatives	

From descriptive to prescriptive culture (G)		
Significant staff reduction (A, B, C, F) New positions for data techs and engineers (A, E, F, G) Internal Production balancing to avoid WIP (B) Quality mgt tower (1 manager for the cluster) (C) No significant impact from I4.0 (G)	Impacts to overall staff	
Staff Trg &qualification (A, B, C, D, F, G) Ecosystem qualification (A, E Hiring experts (A, E, F, G) The Assembly line team must qualify for the entire process, not just a workstation (A, B Intrapreneurship (A, B, C M&A for new capabilities (C, E	New qualifications	
PoC (A) 3-D print (A, B, C, F) Proof of Concept (PoC), Swarm, A3, Design Thinking, MVP, Scrum, Squad, (A, B, C, F)	Fast development	
The concentration of production (A, C, F) ICT suppliers base (C)	Relocation of production	
Lack of plants/systems standardization (A) Digital exposes errors (B)	Barrier to change	Barriers to change

APPENDIX D - Field work results

This Appendix exhibits the cases introduced in section 3.3.2 using the sequence presented in section 3.3.5. Each case summary contains the following items: i) data sources; ii) introduction to the case; iii) description of sites and operations; iv) DT strategies and journeys; v) IIN level evolution; vi) site level evolution. The process described in section 3.3.4 originated the data, coded according to section 3.3.5, and summarized in this appendix. The case reports below are the result of twenty-two interviews, and four site visits totalizing thirty-eight hours, complemented by secondary source searches, webinars, phone calls, and e-mail exchanges

Case A – LORRY, a commercial vehicles manufacturer

i. Data sources

Our primary contact for this case is LORRY's senior sales manager, who hosted a site visit in mid-2019. The primary data sources are interviews with the DT leader, the DT manager, and the after-sales manager. The secondary data sources for this case are the global and local company websites, the annual report from 2019, webinars from industry and commerce associations, press releases, newspaper and magazine articles (Valor Econômico, O Estado de São Paulo, Revista Exame), and corporate videos posted on Youtube.

In September 2019, we had the first interview with our main informant, the industry planning and DT leader, and the process planner. The session took 2 hours, consisting of introductions, a presentation of the research project, an overview of the MNE’s DT program, and discussions on confidentiality terms. In October 2019, we interviewed the after-sales manager twice in two-hour sessions. In 2020 we separately interviewed the DT leader and manager once again in two separate 90-minute sessions via video conferences due to the pandemics. We returned the case summaries for review, addressing eventual pending issues and exchanging phone calls and e-mails with the informants.

ii. Introduction to the case

LORRY is a traditional vehicle manufacturer that belongs to a European industrial conglomerate. LORRY, our current case, and BUS, discussed in Case B below, belong to the same conglomerate. LORRY generates revenues of over USD25 billion and employs more than seventy-five thousand persons worldwide. The Brazilian subsidiary responds for 6% of the global production and 50% of the Latin American production.

iii. The MNE and its Brazilian operations

The global IIN is composed of the global HQ in Europe (Site A1) and two subsidiaries in Turkey and Brazil, the latter headquartered at the industrial complex of LORRY situated in a traditional automotive cluster in the state of São Paulo. R&D at Site A1 develops the global product and service platforms for this IIN. The global HQ also leads two other IINs, one with the US branch and another with Asia, that manufacture specific products for their markets. The Latin American operation counts several Brazilian plants and one in Argentina with the following characteristics:

TRUCK's Brazilian HQ complex started operations in the 1950s hosting several Sites. Site A2 is the largest plant outside of the MNE's home country. It counts with one dedicated chassis and final assembly line operating with I4.0 concepts since 2018, a truck cabin assembly line upgraded to I4.0 in 2020, and shares sub-unit assembly lines for drives, shafts, and transmissions with co-located Site B1 from BUS. Site A2 also holds responsibilities for process development activities and products in warranty.

Site A3 is the regional R&D center for LORRY that adapts global product platforms to the Latin American market. Site A3 still operates using traditional R&D processes to communicate with global R&D and with Site A2. Process planning at Site A2 integrates the local R&D and production functions by transforming the adaptations from R&D into production and equipment resources.

Site A4 is the after-sales operation that recently inaugurated telematics and fleet management service offerings. It is in the same complex as Sites A2 and A3.

Site A5 is a plant that assembles truck cabins. It started operations in the late 1990s. The plant counted with an extra-heavy truck assembly line that recently shut down. The production moved from Site A5 to Site A2's new I4.0 assembly line. Currently, Site

A5 receives stamped sheets from Site A2, welds and paints the cabins, and returns them to Site A2 for final assembly.

Site A7 is a distribution center and traditional after-sales customer center that operates logistics for parts, a remanufacturing operation for specific components, and a training center for the Latin American maintenance network A8*. This Site supports both LORRY and BUS operations, so we name it Site A7 in case A, and B4 in case B, although both refer to the same operation.

The Argentinean Site is A6. It belongs to BUS and is the same Site as B6 that we describe more in detail in Case B. Site A2 supplies CKDs to Site A6 for the final assembly of trucks. CKD stands for “completely knocked-down,” a process where a factory manufactures the vehicle in parts and ships it to another final assembly site.

The IIN also relies on a third-party dealership network that sells products and offers maintenance and repair services in Latin America. We name this network A8*. All sites with an asterisk (*) in this research represent a collection or network of single units. Complement this case the innovation ecosystem that develops apps for the service platforms, A9*, and the business ecosystem that shares the service platforms and apps, A10*. The following section explains the reason we included these two ecosystems in case A.

iv. DT Strategies and Journeys

LORRY has deployed the four DT journeys. Our informants highlighted that DT implementation is a continuous “journey” without an established endpoint, indicating a continually evolving process. In the following paragraphs, we present the DT journeys LORRY is implementing and the resulting transformations at the site and IIN levels.

IIN Integration

At the global IIN level, LORRY developed a process-centric DT strategy aiming at significant productivity improvements for the manufacturing sites and higher integration of the IIN, in line with the IIN Integration DT journey. There are nine thematic clusters in the technology dimension addressing specific applications like logistics or operations. By the time of the interviews, three clusters were operational at the IIN level with global scope: a) digital works support, b) smart automation, and c) flexible production. Some of the projects have a global scope, like the AI project led by Site A2. Others have local scope.

At the plant level, sites hold the responsibility for formulating and implementing their local IIN Integration journeys. For example, by the mid-2010s, the Brazilian subsidiary received the mission to adjust its production lines to the new global product platforms, a vital strategic move for its survival. The existing production lines would not cope with the production forecasts. DT was, therefore, a question of survival. The Brazilian subsidiary took advantage of the opportunity, benchmarked other plants in North America, Europe, and Asia, and implemented the most advanced I4.0 technologies in a new production line following the IIN Integration DT journey.

Site A2 had the autonomy to decide how to upgrade its production process. The renovation took two years. The new I4.0 assembly line’s extra agility and capacity consolidated the former three production lines from Site A2 and the extra-heavy truck production, previously made at Site A5. Hence, a single assembly line in Site A2 centralized the production function for finished products, supported by integrated subunit assemblies at Sites A2 and A5. Recently the final cabin assembly operation at Site A2 also incorporated I4.0 technologies. The I4.0 lines provided a four-fold improvement in productivity. Today, Site A2 is a technological benchmark for LORRY. On top of the nine global technology clusters of the global DT program, Site A2 ground their local DT projects on nine digital technologies (RÜßMANN et al., 2015; STRANGE; ZUCCHELLA, 2017) and a tenth pillar dedicated to people.

The extensive use of digital technologies, the first characteristic of an IIN integration DT journey, is noticeable at Site A2. IoT, CC, and BDA integrate assembly stations and the Automated Guided Vehicles (AGVs) that carry the products along the production line on the production floor. Activities like Quality Assurance also make use of digital technologies like a vision system for tire quality inspection. Lift truck drivers use a tablet system that supports the regular and autonomous lift truck fleet's management, providing a more effective flow of parts and components throughout the plant. Collaborative robots at the cabin assembly line and augmented reality devices at the I4.0-line support operators improve their reliability and productivity. Site A2 has a digital shadow in place that monitors in real-time the physical production flow. The digital twin that will allow operators to adjust the process by actuating on the digital part of the CPS is under construction to integrate the process development, production, logistics, sales, and after-sales functions. Site A2 uses 3D printing to develop prototypes, spare parts, production devices, and maintenance tools. However, the MNE does not use this technology to produce any part of the finished products.

As part of its digitalization project, Site A2 developed internal digital platforms to integrate activities with the other Brazilian and Argentinean plants. Site A2 coordinates the digital platforms to plan and execute production and logistics for the regional IIN, including Sites A2, A5, A6, and the distribution center at Site A7. Site A5 lost part of its production capability by relocating the extra-heavy truck production and implementing the internal digital platforms for production planning and logistics, becoming a cabin supplier to Site A2. Besides the impacts on Site A5, the internal digital platforms also affected Sites A6 and A7 activities, centralizing production planning and logistics for these sites at Site A2. The changes described above align with the second and third characteristics of the IIN Integration DT journey.

Functional boundaries blurring is present in LORRY's case too. For example, Process improvement uses quick prototyping techniques like Proof of Concept, where the team develops solutions and conceptually proves them in quick experiments, tests the approved alternatives in pilots, and rolls them out if successful. The development teams are multifunctional, with representatives from process development, production, logistics, and other support functions as needed. Another example is the intrapreneurship program launched in 2018 to motivate employees to contribute with ideas. The program emulates a start-up enterprise incubator, developing capabilities to present, validate, execute, manage, and even pivot their solutions. The gamification app that we will present in the following sections and several improvements to the manufacturing process originated from the intrapreneurship program.

There is an on-going process to integrate the R&D Site A3 with the production Site A2. The digital tools to transfer data from R&D at Site A3 to process development and engineering at Site A2 are incipient signs of integration. Although the Proof-of-Concept methodology is in use at Site A2 to speed the process and digital service apps development as we described above, our informants did not provide evidence of its use at Site A3, still a traditional R&D site for the adaptation of global products to the local market. For this reason, we keep Sites A2 and A3 as separate operations in the IIN, although the model predicts that they should merge into a single operation with the advancement of the IIN Integration DT Journey.

The previous paragraphs highlighted empirical evidence from LORRY to typify their IIN Integration DT Journey. In the rest of this section, we present other organizational dimension changes that will support the IIN- and Site-level analysis in Sections 4.1.5 and 4.1.6. In the organizational dimension, the IIN formed a DT network to kick-off the DT journey in 2018. Site A1 leads the network that counts with active participation from the Brazilian and the Turkish subsidiaries. The most advanced plant in a theme leads the efforts in that arena. The global network meets weekly to discuss, align, review projects, and submit the proposals to the innovation board of the MNE that determines which plant will lead each project they approve. As reported by our informants, the main barrier to global replication of projects stems from differences in systems, operational processes, and culture in each of the plants.

A critical organizational development for Site A2 was the appointment of a DT leader, the process development and industry planning manager, reporting directly to the Brazilian subsidiary's Chief Operations Officer. Besides, Site A2 decentralized the management of DT projects. Each manager leads a theme on top of their traditional responsibilities, indicating a matrix structure for implementing the DT process. ICT plays a supporting role in LORRY's DT journeys.

To handle digital technologies, the training and capacitation of personnel occur with external partners like SENAI, a Brazilian network of technical schools. Qualified employees operate new technologies like the AGVs that replaced the traditional assembly lines. Moreover, to ensure only qualified personnel operates equipment, an intelligent access system using the individual's badge provides access to workstations based on the employee's qualifications. Employees use augmented reality devices for training, operation, maintenance, quality, and logistics activities.

DT did not change the factory's essence in the organizational dimension but the "how-to" work. Before the transformation, operators used manuals and hard copy written procedures, while today, they use interactive human-machine devices and virtual reality. Production teams that worked under lean manufacturing concepts before DT maintain the same organizational structure in the new logic to operate the I4.0 line, suggesting that "lean" precedes "I4.0". For example, Site A5 hosts a manufacturing engineering team that develops the welding and painting processes and contributes to improvements to processes and products through intense cooperation with process development at Site A2. Site A5 uses a lean-based work system that supports an excellent history of continuous improvement and employee engagement.

Cultural adjustments for DT rely on several pillars. The first one is the training and qualification of supervisors, leaders, and selected operators using a simulation of an I4.0 factory from SENAI to introduce the concepts of "pulled line," AGVs, quality control in real-time, and logistics. The qualified multipliers disseminate these concepts to the manufacturing crews. A second effort is the intrapreneurship program described above.

Life-cycle Integration

LORRY's Servitization strategy, described in the next section, uses mobile apps originated by client's requests or as LORRY's initiatives. The professionals that develop local solutions and apps are LORRY specialists in Site A4, five associated external developers, and LORRY employees that joined the internal intrapreneurship program presented in the IIN Integration DT Journey above, representing a dispersion of the R&D function for digital services. Together, they form an innovation ecosystem, A9*, integrated by a digital platform that is, at the same time, industrial and business in its characteristics, therefore including customers and drivers too. Some examples of apps developed by the ecosystem A9*, detailed in the next section, are the fidelity reward program, a gamification app to support truck drivers, and the legal requirement app. There was no evidence of the Life-Cycle integration DT journey for physical products, suggesting that this is still an opportunity area for LORRY according to our conceptual model.

Digitally Enabled Servitization

The following paragraphs describe the empirical evidence that typifies a Digitally Enabled Servitization DT journey at LORRY. The HQ, represented by Site A1, develops the hardware, IoT technologies that provide connectivity to the products, and the digital platforms that use the data from the field to enable a range of service offerings like product and fleet management services. Each subsidiary chooses which technologies from the HQ's portfolio to implement in the local market. LORRY Brazil selected the telematics platform for truck performance management and fleet logistics management services, both characterizing intermediate servitization in the transformation model from Baines et al. (2020). The truck is still the main product sold, while associated digital service offerings complement the MNE’s portfolio. According to our informants, local clients refuse advanced service solutions because they still prefer to own tangible products.

Considering the technological dimension, digital platforms and the onboard firmware comprise the core of LORRY's servitization DT journey. The existence of services associated with products depends on the real-time update of intelligent products' parameters on the road. Trucks count with onboard sensors and processors that generate the data for performance monitoring. IoT connects the trucks to the telematic or fleet management platforms using digital technologies like CC, BDA, and AI to form a CPS representing the truck or the entire fleet.

The digital telematics platform integrates the physical trucks in the field and their digital twins in real-time, anticipating problems like breakouts, suggesting adjustments, recommending maintenance actions, providing guidance to the drivers, and preparing the service network for necessary maintenance work in advance, optimizing the trucks’ performance. The introduction of the telematics platform to manage the performance of products in operation offers transparency and agility, enabling a proactive approach that simplifies a historically complicated communication process among customers, the after-sales organization, the service centers A8*, the traditional technical assistance at Site A7, and the production Site A2. The Telematics platform monitors every connected truck in Latin America, offering drivers guidance to their road journeys, and managing preventive maintenance.

The fleet management platform integrates orders, routes, trucks availability to optimize the fleet uptime, minimizing stops and idle units. The fleet management platform configures the routes to minimize stop times that traditionally consume 60% of the operation time. The digital platform avoids up to 80% of unplanned stops. In theory, the CPSs from the telematics and fleet management services could run automatically, but the MNE leaves decision-making to the customers who own the products and their fleets' operation.

Considering the organizational dimension, LORRY created Site A4, a control center co-located with A2 to cope with the new service offerings. Site A4 manages the digital platforms for both services under the coordination of the after-sales function. The digital platforms support the MNE’s servitization journey, integrating products, customers, service providers, and the manufacturer. The platforms allow the MNE to detect an issue even before the client is aware of it, enabling preventive actions that minimize the losses for all parts. There is an integration of Site A4 with Site A2 for products in warranty and the network of authorized workshops A8* through the digital platforms, replacing with a predictive approach the traditional corrective approach where LORRY would learn about an issue only when the customer reported it. R&D also benefits from the digital platforms by collecting data of products in the field in real-time that Site A3 uses for further product development.

The creation of the control center, Site A4, required twenty new positions for digital technicians and engineers to monitor and manage the digital platforms while the traditional technical support staff suffered a reduction in the same proportion. The maintenance teams at the dealers' network A8* were qualified to use the services platforms and prepare their work ahead of the truck arriving at the shop. Maintenance operations are faster and more reliable because of these platforms and digital technologies. For example, augmented reality devices help mechanics to complete their work quickly. The cultural adaptation to these new services offering goes beyond the employees from LORRY. A customer-oriented culture also intends to foster the platforms' adoption and induce a preventive culture in clients and drivers, as detailed in the next paragraph.

A second element of the Digitally Enabled Servitization journey in LORRY is introducing mobile apps for truck drivers to support the business ecosystem A10*. LORRY launched the first fidelity reward program ever in the Brazilian commercial vehicle market. Its work principles are like an airline mileage program. A second app supports drivers' qualification through gamification, which rewards the best driving practices and equipment operation. Another app monitors the workload of drivers so that they comply with local legal requirements. These apps intend to engage customers and end-users to increase their brand loyalty.

Relocation

The only evidence for this DT journey was relocating the extra-heavy truck production from Site A5 to Site A2. The motivator was the I4.0 line's extra capacity, flexibility, and agility. The movement was a consequence of the DT journey of IIN Integration. We did not find evidence of 3D printing as a motivator for production relocation. As we covered in the previous sections, that technology finds significant use in fast prototyping, tooling, and spare parts manufacturing, but not in finished product manufacturing in this case. We also did not find a specific economic platform that supported the production relocation. Although the I4.0 line agility theoretically would enable LORRY to customize products, our informants told us that production orders are oriented to build inventory, not fulfill purchase orders. We conclude that the production relocation occurred due to the IIN integration DT journey and not as a specific effort to improve LORRY’s customization capability.

v. IIN-level evolution with DT

According to the model from Shi and Gregory (1998), the configuration of the global LORRY’s IIN is multinational, as it has operations in different regions and countries, the HQ in Europe, two subsidiaries, one in Turkey and one in Brazil. The South American IIN has **a** regional configuration with Sites A2, A3, A4, A5, and A7/B4 operating in Brazil, Site A6 in Argentina, and the service network A8*, the innovation ecosystem A9*, and the business ecosystem A10* across Latin America. Therefore, the configuration remains unchanged in both IINs with the implementation of the DT journeys.

On the other hand, there are changes in the IINs’ coordination, originally multi-domestic**,** where each subsidiary was autonomous to make local decisions. The plants' historical autonomy led to different systems and processes, inhibiting digital solutions replication thanks to a lack of standardization across plants. DT brought higher integration to the IINs, where plants discuss, agree, and allocate projects in a DT network, an effort that indicates a tendency towards an IIN-level of coordination. Contrary to the global coordination from Shi and Gregory (1998), where the HQ coordinates all activities for the IIN, in the present case, coordination takes place among all participants of the IIN, thanks to the data IIN Integration DT Journey. Therefore, the global IIN is evolving from a traditional multi-domestic network (SHI; GREGORY, 1998) to a form of network coordination not found in Shi and Gregory's typology. While the IIN’s configuration remains unchanged, there is higher integration inside the IIN with increasing standardization of products, service offerings, and processes. Accordingly, the regional IIN has also evolved from a regional focus network to a new type of regional network, with higher coordination among the Brazilian plants, the Argentinean Site A6, the mechanical shop network A8*, and the innovation (A9*) and business (A10*) ecosystems spread in Latin America.

vi. The evolution of the role of plants with DT

The first dimension that determines the plant's role is its strategic reason to locate. Site A1's strategic locational reason is access to knowledge and skills to develop, manufacture, and coordinate the global IIN. Brazil is a significant market in Latin America, corresponding to about 50% of the regional volume. The decision to locate Sites A2, A3, Site A7/B4, and the network A8* follows the logic of proximity to the market. Taxes exemptions motivated the MNE to locate Site A5 farther away from the largest Brazilian markets, characterizing the strategic reason of low production cost. The reason to locate plant A6 in Argentina is the proximity to that specific market. We did not observe changes in this dimension along the DT process. LORRY followed the logic of access to competencies and knowledge to locate the new control center A4 together with Site A2. As a result, A2, A3, and A4 co-locate, although they still operate independently. The network of mechanical shops A8* is located close to markets and the business ecosystem A10*, formed by fleet owners and truck drivers. The innovation ecosystem A9* requires specific skills and knowledge.

Site A1 is a lead role in the global IIN since it is the global reference for the products and service platforms developed for the IIN. Site A2 is a contributor plant in the Ferdows' model, combining the strategic reason to locate based on the proximity to market, its active participation in the global IIN as a manufacturer and process developer. Site A2 assumed extra activities that reinforced its role in the IIN, such as the leadership of several digitalization processes, the coordination of the regional production planning and logistics platforms, allied to significant advances in DT's technological and organizational dimensions. Site A2 also co-locates with two sites that would not be part of the traditional models. Site A3 is the regional R&D center that tropicalizes products not yet fully integrated into Site A2. Site A4 is a new control center to monitor and manage new service offerings for Latin America. Looking at the Regional IIN, if Sites A2, A3, and A4, today weakly integrated operations, proceed with their data integration DT journey, they may consolidate a single site with a lead role for the regional IIN.

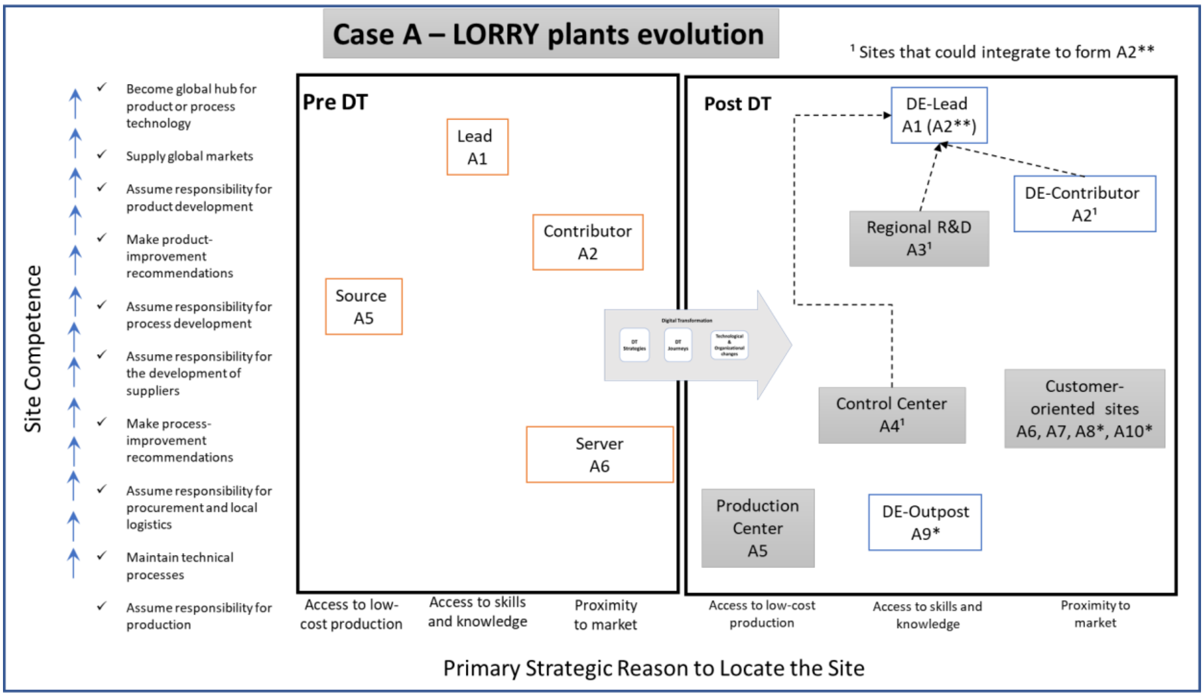
According to Ferdows' model before the DT, Site A5 had a Source role. It lost the truck production line due to the IIN Integration DT Journey. Site A5 also lost logistics and production planning management but increased higher-order capabilities, now enjoying high integration with Site A2, thanks to the IIN Integration DT Journey. Site A6 had a Server role. It continues to assemble CKDs made by Site A2, with fewer management activities and more participation in the IIN like Site A5. Considering the model from Ferdows, Sites A5 and A6 changed their roles, losing some activities but gaining digital capabilities and higher integration to the IIN.

Site A7/B4 was not part of the IIN, according to Ferdows, since service providers do not fit in his model. Its activities characterize a complex Service and Distribution Center. Site A7/B4's strategic reason to locate is the proximity to markets since it supports the network of mechanical shops and dealers A8*, coordinating spare parts supply to distributors and customers. Site A7/B4 develops activities of distribution, traditional customer services, and training centers. The Data IIN Integration DT Journey introduced Site A7/B4 into the IIN through the logistics digital platform led by Site A2. The advantages for Site A7/B4 are inventory reduction and faster service delivery to customers because the digital platforms improve the integration of the value network, balancing the demand and supply of parts stored in the Distribution Center.

The Digitally Enabled Servitization DT Journey integrated the dealers and authorized maintenance shops A8*, spread across Latin America, into the IIN. Although LORRY does not own the service centers, they are part of its business ecosystem, A10*, supported by digital service platforms. Finally, the innovation ecosystem A9* that supports Site A4 combines access to knowledge and the development of support systems using the DT Journey of Life-Cycle integration. Had they the production function, they would be Outpost Sites in Ferdows model.

Figure A represents the evolution of LORRY's sites from before to after implementing the DT process. Note that Site A2** represents an eventual future state where Sites A2, A3, and A4 integrate into a single site with the lead role. We grouped Sites A6, A7, network A8*, and the ecosystem A10* under the same type because they share a similar reason to locate and activities focused on customer satisfaction.

Figure A – CASE A – Evolution of the plants in LORRY



Source: The author

CASE B – BUS, A COMMERCIAL VEHICLE MANUFACTURER

i. Data sources

Data sources for the BUS case are the same as for LORRY. Our initial contact for BUS was our main informant for LORRY, who introduced us to his counterpart in BUS. Interviews took place via two 90-minute videoconferences in the first semester of 2020, completed by e-mail messages to clarify the remaining points. Face-to-face contact was not possible because of the COVID-19 pandemics restrictions.

ii. Introduction to the case

BUS is a traditional manufacturer of all types of buses. Previously a division from LORRY, it became an independent business in the 2000s. BUS has annual revenue in the order of €5 billion and employs twenty thousand persons worldwide. The global IIN has the HQ in the home country and subsidiaries in Europe, the Americas, and Asia. The Brazilian subsidiary is responsible for at least 30% of the bus chassis produced globally. In Brazil, BUS develops and produces bus chassis for both city and interurban vehicles in the completely built-up (CBU), semi-knocked down (SKD), completely knocked down (CKD), and KIT modes. CBUs are ready-to-use chassis made for the local market, CKDs are partially assembled vehicles exported to other plants for final assembly, and SKDs are part of the development phase of CKDs. The CKD integrates more than 40% of the corresponding CBU's value with product management by BUS. If the assembly does not meet these criteria, BUS considers it a client's KIT. The difference is that BUS includes CBUs and CKDs in their production and sales statistics but not KITs. Our current research focuses on BUS's global chassis IIN led by the Brazilian subsidiary.

iii. BUS's global chassis IIN

The global chassis IIN has plants in Brazil, Mexico, Argentina, Egypt, Indonesia, and South Africa. Site B1, co-located with site A2 from case A, is the largest global chassis manufacturer for BUS. It started the production of buses in the late 1950s, transferring the operation to Site A7/B4 in the 1970s. When BUS discontinued the production of complete buses, the chassis assembly operations returned to Site B1. It counts with a dedicated assembly line that recently upgraded to I4.0 concepts, an independent chassis R&D center that is the global reference for BUS, and the subunits assembly lines shared with LORRY as presented in case A. The colocation with Site A2 favors Site B1 with an intense exchange of capabilities and knowledge. Compared to TRUCK, the smaller size of BUS facilitates the integration of R&D, process development, and production, critical for developing the CBUs, SKDs, and CKDs for the IIN.

The chassis platforms developed and made at Site B1 include a wide variety of configurations for microbuses, inter-city, long-range, and city buses, including articulated versions widely used in public transportation. Site B1 develops and manufactures CBUs, SKDs, and CKDs for the local market, exports to thirty-one countries, including other BUS plants, and clients in Latin America, Africa, and Asia. With such a wide range of products, the I4.0 assembly line confers Site B1 a competitive advantage due to its flexibility and agility to adapt to new products and production mixes. Site B1 also manages the capacity planning for Brazil and Argentina. Therefore, Site B1 operates in four market models: a) Brazil, b) Argentina, c) Latin America, and d) overseas. The plant works like an "order center" that organizes these four different models.

Plant B2 in Mexico operates as an independent unit with a full range of manufacturing activities from R&D through after-sales services. Site B2 develops and makes custom products for the Mexican market. BUS assembles the chassis, while a partner firm completes the fully equipped bus assembly. BUS recently incorporated its Mexican subsidiary into the Latin American IIN. Site B2 should lose some of its capabilities to Site B1 as part of the network integration efforts. Although DT might play a role in this transition, it is not the driver for the reorganization.

The chassis IIN recently joined BUS's global supply network. Site B3, a global consolidation center, coordinates worldwide parts supply like engine blocks and bus articulations for all the MNE's plants. This center aggregates the needs of the IIN, develops global suppliers, and determines the flow of materials for the MNE. For example, the bus articulations come from the home country, whereas a plant in Asia produces engine blocks for the entire company, not just the chassis IIN. The advantages are reducing global inventories, materials flow optimization, and improved negotiating power with global suppliers. The other side is the higher dependency from the global suppliers that may increase lead times and generate material shortages.

For example, the recent COVID 19 pandemics halted all production in the first quarter of 2020. The countries that restarted operations earlier faced a shortage of materials because suppliers from other countries were still down. Integrating such differences and providing a high standard service is the consolidation center's mission. LORRY, in Case A, will soon join the Consolidation Center too. Although Site B3 locates in BUS' home country, it plays an essential role in the chassis IIN, so we consider it in our research.

We already discussed Site A7/B4 in case A. It started operations in the late 1970s as a bus assembly factory, but this operation shut down a few years later. Site B4 belongs to the BUS division and serves LORRY as well. The operations in Egypt, South Africa, and Indonesia complete the IIN as B5*. They assemble CKDs supplied by Site B1 and sell them to the African and Asian markets. Site B1 R&D center develops the products and CKDs for B5*. The plant in Argentina, Site B6, already described in Case A as Site A6, assembles chassis developed at Site B1 on CBU and CKD modes for the Argentinean market.

iv. DT Strategies and Journeys

BUS plants hold the responsibility for formulating and implementing their specific digital strategies with relative independence from the HQ and higher autonomy than LORRY plants. The co-location with Site A2 provides Site B1 with a competitive advantage due to knowledge spills between the two divisions. Site B1 is the most advanced plant in DT inside the BUS division.

The leading digital strategy in place at BUS in Brazil is Integration. BUS reapplied the IIN Integration DT journey from LORRY with the same objectives of productivity increase at the plant level and network integration at the IIN level. Site B1 coordinates the internal digital platforms for production planning and logistics, integrating the IIN operations of Sites B1 and B4 in Brazil and B6 in Argentina. The CKD assemblers B5* take part in the logistics platform in the same way as other regular customers from BUS as they manage their production and sales independently from Site B1. Eventually, Site B2 in Mexico will join these platforms too. Site B3 coordinates global supplies procurement using an internal platform, as we described in the previous section.

At the plant level, the new I4.0 line at Site B1 incorporated the learnings from Site A2, integrating production processes and plant functions. There are a few remarkable differences in planning and implementation, however. The first one is that the line can accommodate current and future technologies, providing agility for the subsidiary to choose and incorporate new features into future products. The second is to synchronize a line with vastly different products, generating stations where complex products have preference over simpler versions to optimize the production flow. A third difference is that the project team developed the factory's digital model before its physical counterpart, allowing the early identification of issues and their resolution still in the project phase. The model became the factory's digital twin as it started operations in 2020, leapfrogging the digital shadow stage that we presented in case A.

At Plant B1, products range from short microbuses to long-articulated buses. Each version, in its turn, has different configurations related to suspension type, floor height, front or back engine, right or left steering, and gas emission control systems to meet EURO 2 to EURO 6 standard requirements. The AGV line can assemble the full range of products without change-over stops. The new product flow logic incorporates flexibility and agility to the production process. However, measuring the production volume at the end of the line is no longer enough to balance production at an I4.0 line. It is necessary to set targets of line occupation to avoid unnecessary work-in-process. Each workstation's length can change, enabling the planner to set the number of active AGVs and operators across the production line. This way, the number of workstations and the borders between them are fluid. An extreme situation consists of a single workstation that will assemble an entire vehicle. Therefore, the assembly team should be qualified to operate any part of the assembly line, a higher qualification level than required for traditional lines. To facilitate the assembly operation, operators use checklists available at the Man-Machine interfaces moving along with the workstation.

Although there is already strong interaction between the production and R&D functions at Site B1, several changes to promote the speed of development and implementation of new products and processes configure a Life-Cycle Integration DT journey. One technological change is building a digital document library kept in a data lake as a data repository, allowing real-time data sharing across functions. Another change is implementing the e-center, an electro-electronic system, to enhance the cooperation between the two areas. The digital library and the e-center configure digital industry platforms for product development.

According to our informant, an essential organizational change was introducing “swarm” methodologies and multifunctional teams. These solutions sped new products' development and dispersed the R&D function across the organization, forming an innovation ecosystem that works better with the new generation of professionals. Another change in the organizational dimension was implementing cultural change programs to avoid resistance from the traditional departments. DT makes failures and mistakes more evident. The cultural programs apply to all employees, are available online, covering elements like customer focus, empowerment, and intrapreneurship. The initiatives we described above are more advanced in BUS than in LORRY. We consider R&D and production as a single operation in case B, whereas in case A, they are still two formally separated sites, a statement supported by the fact that the BUS operation is smaller than LORRY’s and requires higher integration to develop new CBUs, SKDs, and CKDs.

Servitization strategies exist for fully-equipped buses made in Europe and North America, like those available for trucks. BUS is considering offering part of the service packages related to product performance monitoring, but the model is still under development. BUS clients are not the final users like in case A but finished product assemblers, hindering direct replication. We did not observe any evidence of a relocation strategy in this case.

v. IIN-level evolution with DT

The chassis assembly IIN, including the plants described in 4.2.3, has a multinational geographical dispersion. Although we did not directly cover BUS's global IIN, it is worth mentioning that its plants have a low level of interaction and are autonomous in developing their products and processes because of different configurations and needs of their markets, a multi-domestic coordination mode (SHI; GREGORY, 1998). With DT, the HQ of the global IIN coordinates global meetings to develop strategies to launch new products, balance production, and allocate resources. Plants from all regions actively participate by proposing the projects they will execute to meet the IIN's objectives and competing for the required resources. There is global coordination of some activities like procurement by the recent Consolidation Center B3. The global IIN in BUS presents the same evolution as its counterpart, LORRY, although BUS's transition is not as evident as LORRY's.

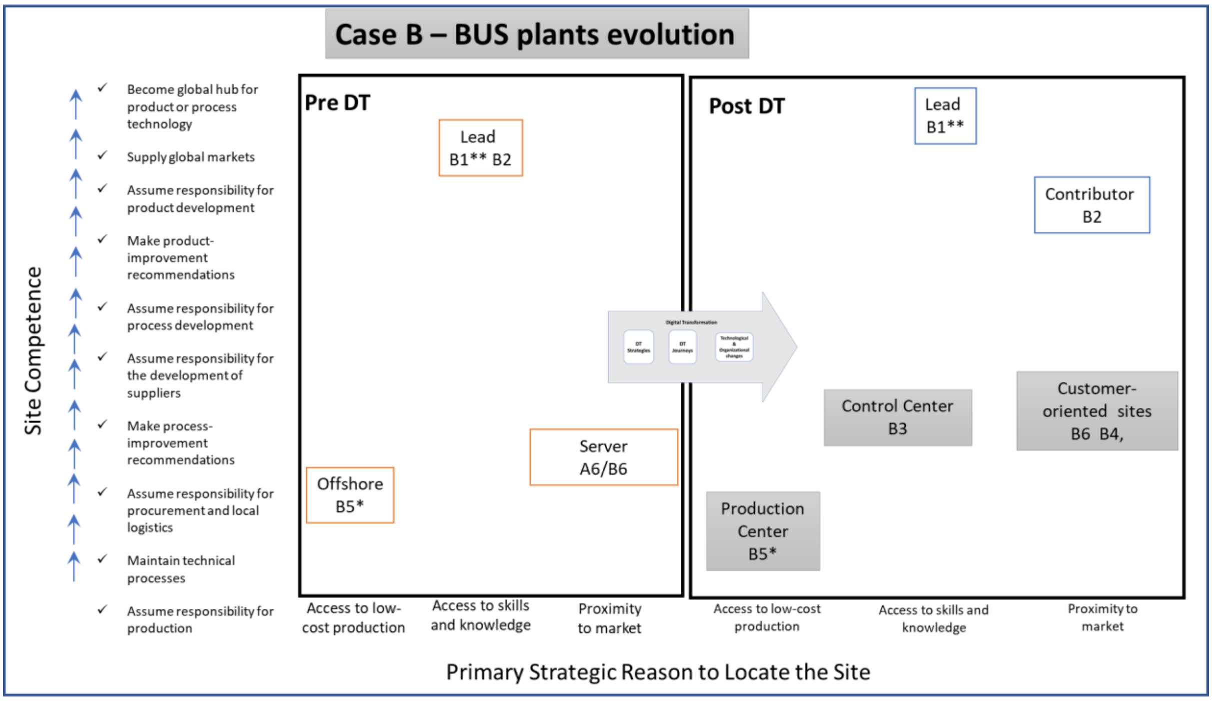
Site B1 leads the chassis IIN, coordinating internal platforms that increased the integration with Sites B4 and B6. Because of its recent incorporation into the IIN, Site B2 in Mexico is still autonomous but should lose some management activities to Site B1 as part of an organizational simplification process. The CKD assembly operations B5* are autonomous in planning their production and selling their products but depend on Site B1 to develop and manufacture their CKDs. The Latin American planning and logistics platforms led at Site B1 integrate the Latin American plants. In the chassis IIN, the coordination is evolving from multi-domestic to network, like in case A.

vi. The evolution of the plants with DT

The relevance of local markets in Brazil, Argentina, and Mexico justifies the BUS plants' location in Latin America. The co-location with LORRY's operation and its geographical location inside an important knowledge center in Brazil also favor the location of BUS in Site B1 plant. The Mexican subsidiary also benefits from the USA's closeness to export part of its production to that market.

BUS implemented DT using the integration strategy focused on productivity enhancement for Site B1. Site B1 has a lead role in the chassis IIN based on the combination of strategic reasons to locate and the site's responsibilities. The IIN Integration DT Journey promoted the integration of the activities at the plant level. Besides, internal digital platforms combine activities that previously belonged to each site in the network, like production planning and logistics. The Life-Cycle Integration DT journey sped the development and deployment of new products, reinforcing the global reference position Site B1 enjoys for bus chassis.

Figure B - CASE B - Evolution of the plants in BUS



Source: The author

The Mexican Site B2 had a lead role before moving into the Latin American IIN. After incorporation, it became a contributor site. The change in role occurs because of a strategic reorganization of operations. DT, in this case, might act as an enabler to integrate Site B2 into the IIN. Site B4, the same as Site A7, has the same role in the IINs from LORRY and BUS. It is not part of the model from Ferdows, but now it is an active part of the IIN as we explained in Case A. Plant B6 in Argentina, the exact location as Plant A6 in case A, is a server plant in the Ferdows model. It loses production planning activities but continues manufacturing products specifically for the Argentinean market with higher integration using the internal digital platforms. The

CKD assembly plants B5* are offshore plants in Ferdows' model, now better integrated into the IIN through the digital platforms.

The global Consolidation Center B3, not considered under Ferdows' model, coordinates the procurement of critical parts for BUS' global operations, including the chassis IIN object of this study, an activity previously taking place at plant level now transferred to the IIN level. Figure B illustrates the evolution of the IIN in Case B.

Case C – CONFAST – A Fast Moving Consumer Goods company

i. Data sources

Our primary contact and the first primary source of data for this case is the director of supply chain and quality. He introduced the other primary source, the director of supply chain and DT. The first round of interviews took place between September and December 2019, and the second round in June 2020. In the first round of interviews, we had an introductory 60-minute phone conversation, two 90-minute face-to-face meetings with the DT director, and a 90-minute phone call with the quality director. A second 60-minute interview with the quality director in June 2020 provided additional information. We also exchanged e-mails to complement data from the interviews. As secondary sources of data, we used the global and Brazilian websites of the MNE, websites of their partners and service offerings, annual reports, brand homepages, and articles published in the media.

ii. Introduction to the case

CONFAST is a traditional European firm in the fast-moving consumer goods sector, present in over 190 countries with more than four hundred brands, several of them earning revenues above €1 billion per year, sourced by about three hundred plants globally. The MNE's total revenue in 2019 was over €50 billion, 15% from Latin America. There are three main divisions in CONFAST, two responsible for 40% of the global revenue each, and the third division for the remaining 20%. All divisions own global and local brands that are market leaders in their segments. CONFAST has regional clusters on all continents. The MNE owns twenty-one plants in Latin America, ten of them in Brazil. The importance of the Brazilian subsidiary and the implementation of successful DT projects justify selecting this case in our study.

iii. The MNE and its Brazilian operations

CONFAST concentrates on manufacturing in few countries that export most of their production, except for countries like Brazil, the USA, India, and China, where the local markets are large enough to consume most production volumes. Regional clusters operate autonomously. Brazil is an independent subsidiary in the Latin American cluster, given the relevance of its local market.

CONFAST counts with leading global, Brazilian, and regional brands from all global categories of the firm. The Brazilian network of operations has developed over several decades since the beginning of the twentieth century. CONFAST brands are proprietary or stem from a series of mergers and acquisitions (M&As) that started in the 1970s, including large Brazilian companies.

CONFAST's Brazilian IIN has one HQ and nine sites, four located in the South Eastern and four in the North Eastern Region. The HQ holds sales, marketing, and administrative support. Site C1 is a regional hub with production for the three divisions and a Regional R&D center. While Global R&D concentrates in five global poles, three in Europe, one in the USA, one in China, and one in India, Regional R&D centers exist in strategic countries like Brazil. The main activity of a Regional R&D center is to tropicalize products for local markets.

The remaining operations in South-East Brazil are production sites. Site C2 started operations in the late 1970s, serving the two largest divisions of CONFAST. Site C3 manufactures a single high-volume product since the early 1980s. Site C4 is a new site following sustainability principles, and Site C5 supplies traditional products for the smallest division of CONFAST.

The North-Eastern region of Brazil hosts four plants and a control tower. Sites C6 and C7 supply different products for CONFAST's smallest division. Site C8 supplies regional brands for the same division as Site C3. Site C9 is the newest plant in that region, making products for the two largest divisions for both the local market and for exports. The control tower for the region, C12, will be co-located with one of the Sites in Brazil's north-eastern region.

In recent initiatives, CONFAST decided to explore new markets to meet the increasing demand for specific customers. The MNE started an M&A and joint-venture effort to gain the required capability. We call C10* the new acquisitions and partners, niche start-ups, currently totalizing twenty different small companies. A second initiative was the M&A of a network of consumer service centers that now adopted one of the largest brand names from CONFAST. We call this service network C11*.

Two ecosystems complete the IIN. The First one is a marketplace, C13*, offering CONFAST's and other manufacturers' products, including direct competitors. The advantage of this marketplace is that customers can purchase directly from the manufacturers instead of distributors. Finally, C14*, an innovation ecosystem, develops new products for CONFAST through an industry platform that integrates R&D and a network of internal and external partners.

iv. DT Strategies and Journeys

To drive DT efforts, CONFAST in Brazil applies the Boston Consulting Group model (RÜßMANN et al., 2015; STRANGE; ZUCCHELLA, 2017). According to that model, the Brazilian subsidiary is at an intermediate stage of digitalization. Our informants at CONFAST also call the implementation of DT a "journey," in line with the DT Journey construct. Below we detail CONFAST's DT journeys.

IIN Integration DT Journey

The driver for this DT journey at CONFAST is to increase its value chain, reflected in lowering costs and improving productivity, a process-centric strategy. Since the 2000s, CONFAST introduced global systems for planning, procurement, and manufacturing using digital tools. The global systems were predecessors of internal platforms, representing an early Integration DT strategy.

Currently, the core of the **DT Journey of IIN Integration** at the Brazilian subsidiary is the control tower. A control tower centralizes the operation of manufacturing activities using a variety of digital technologies and internal platforms. CONFAST has several control towers: the logistics tower, the quality tower, the process tower, the planning tower, and the maintenance tower. The objective of each tower is to coordinate the respective systems for several plants. According to the activity, the tower can support a cluster of plants, a subsidiary, or an entire region, thanks to digital twins that support each tower. This arrangement centralizes management systems and allows plants to focus on other activities.

The first tower to operate was the logistics tower at Site C1 in 2010. It coordinates the logistics operations of the Brazilian and South Cone subsidiaries. Similar towers exist in other regions, like Panama for Meso America, the USA for North America, and Poland for Europe. The second type of tower is the Process control tower. It works as a digital twin, reducing the plants' energy consumption by 30%. Although capable of operating automatically, humans overlook the systems and take the final decisions. Site C1 is the global pilot for the process tower, an example of the “top-down” implementation of a project triggered by global HQ in partnership with a digital platform provider. Other control towers like Quality or Maintenance are “bottom-up,” proposed and implemented by the subsidiary. Other units reapply well-succeeded pilots. For example, eight plants around the globe are implementing the digital twin model from Site C1.

Quality and Maintenance towers are recent developments. Quality towers have two centralization modes. The first mode is a quality service center providing laboratory, supplier management, and quality systems analysis and management. There are two quality service centers in Brazil, one for the southeastern plants located at C1 and another for the northeastern plants, named C12. The second mode of Quality tower is the quality management tower. It counts on a single manager for several plants' data management, simplifying the organizational structure. Supporting the Quality towers, cobots and other digital tools allow the reduction of off-line analysis and enable the automatic correction of critical parameters in automated process controls. An automated Certificate of Analysis program for suppliers is also under implementation. The Latin America region will reapply the Quality and Maintenance towers, reinforcing the leadership role of Site C1 in the DT process of CONFAST.

Regarding the technological dimension of DT, the implementation of control towers counts on the support of several digital technologies. Cobots support operations at the end of the production lines, typically for on-line quality tests. IoT enables highly automated plants like C5 to operate and integrate their systems. CC and BDA build data lakes integrating several functions, optimizing product development, production planning, supply chain flows, quality, maintenance, and logistics management with the respective control towers. Sales and orders take place via apps that load data into the data lake. 3D printing allows faster development of prototypes, and agile replacement of broken parts, reducing spare parts inventories. Robotic process automation enables paperless and automatic processes, identifying trends through machine learning and AI. Site C6 pilots an augmented reality system for the training of operators with potential replication across the MNE. Tablets support fieldwork managed by control towers and executed on the shop floor or in the market.

Looking at DT's organizational dimension, a characteristic of CONFAST's process-centric strategy is to use its lean manufacturing program as a pre-requisite for its IIN Integration journey. According to our informants, streamlining and optimizing work processes precede DT as part of the DT journey. CONFAST implemented lean manufacturing in the 2000s, at the early stages of DT. Schuh et al. (2020b) also report this sequence of events in their implementation cases. Another essential organizational decision CONFAST took at the beginning of their journey was to separate ICT and digitalization. The MNE appointed a DT leader from operations. ICT supports the DT according to the priorities set by operations.

The implementation of DT resulted in a 4.5-to-1 reduction in operating personnel. Activities brought to the control towers had a lower impact on workforce reduction. DT requires qualified operators at the control towers and on the plant floor. CONFAST offers training for such technologies and other fast development tools like design thinking to their employees. To accomplish the required cultural changes, Human Resources at CONFAST implemented an intrapreneurship program to engage employees from all functions. The program intends to identify and solve opportunities across all areas of the firm. Proponents of a project present a 3-minute video evaluated by a management committee in up to 48 hours. If approved, the project receives a budget and has a four-month completion deadline. According to the project's needs, teams organize themselves and receive training for entrepreneurship, leadership, project management, and other required skills. CONFAST considers the return of these projects ten times higher than traditional projects, including R&D projects led by the production function, a sign of functional boundaries blurring. The cultural transformation effort in CONFAST focuses on simplification, autonomy, and agility.

Life-Cycle Integration DT Journey

To accelerate R&D processes, CONFAST uses a Life-Cycle Integration DT Journey consisting of global initiatives to integrate the traditional R&D structure with a dynamic innovation ecosystem, C14*. CONFAST created a digital industry platform that connects R&D with external partners, especially start-up firms, to develop new products using agile development tools, including 3-D printing for prototypes, concepts like the Minimum Viable Product, SCRUM, and SQUAD programs, the last ones attached to global initiatives. CONFAST workers from any area can also join the digital industry platform. The HR intrapreneurship program that we described above provides the employees with the required capabilities and tools to create informal multifunctional teams for rapid development initiatives. Our informants observe the diffusion of these structures and tools into the formal R&D structure at Site's C1 regional R&D center. While lean manufacturing provides continuous improvements, the innovation ecosystem generates disruptive solutions. In addition to the DT leader's appointment, described earlier in this case report, the MNE also adjusted its ICT structure. Traditionally a single firm was responsible for the entire ICT management at CONFAST, resulting in a rigid, inflexible system. Today, according to the type of project, ICT suppliers can be large MNEs, start-ups, or even internal multifunctional teams. ICT suppliers complement the innovation ecosystem C14*.

Digitally Enabled Servitization DT journey

The long-term corporate Servitization strategy is to increase focus on the market, especially customers and consumers. As part of its Digitally Enabled Servitization DT Journey, CONFAST joined a digital economic platform consisting of a marketplace shared with other suppliers. The marketplace enables small retailers to place orders and purchase directly from the manufacturers at a lower price than traditional channels, forming a business ecosystem called C13*. The marketplace offers a service that approximates the participating manufacturing MNEs to the complex network of small customers.

Another component of CONFAST's Servitization journey was acquiring a services company, C11*, renamed after one of CONFAST's most traditional brands. The network C11* offers services using brand products from the MNE. Both the marketplace and services company are recent initiatives that require more time for proper evaluation. To conclude this section, it is worth mentioning that contrary to Case A above, CONFAST does not report any intelligent product initiative as part of a DT strategy, possibly because final consumers will use their products shortly after purchase.

Relocation DT journey

The first evidence of the Relocation DT journey at COMFAST occurred in the 2000s. By then, CONFAST created Global or Regional plants using I3.0 technologies to digitalize substantial throughput processes and meet high-volume products' demand. At that time, the justification for such plants was that they would provide standardized products to meet the increasing customer requirements worldwide. High-volume plants were able to improve product quality at a lower cost. Site C1, for example, is one of three plants worldwide that produce one of CONFAST’s most valued global brands. Even with I4.0 technologies, the global plants continue to be relevant strategic factories for making large-volume products.

On the other hand, the increasing demand for customized products requires small-scale production of various versions, differently from the global plant concept. To cope with this new trend, CONFAST implemented a Relocation DT Journey by either acquiring or partnering with start-up companies to exploit market niches with potential future growth. There are currently around twenty such initiatives in progress that we collectively call C10*. Despite their small size, they are the fastest-growing businesses for the MNE today. On the technological dimension, niche operations provide CONFAST the capability to manufacture new trendy products, some of which relocated to their traditional plants. On the organizational dimension, the main issue is integrating these small businesses into the MNE's corporate structure, a challenge not yet fully resolved.

Contrary to the literature, we did not find evidence of 3-D printing technologies to materialize this DT journey. Another element absent in CONFAST’s journey is the use of economic platforms to support the customization firms. Nevertheless, the strategic intent of fostering higher IIN agility is present.

v. IIN-level evolution with DT

The geographic dispersion of the global IIN from CONFAST is multinational since it manufactures in few countries in all regions. The typical factory from CONFAST exports most of its production, except for large strategic markets like Brazil. CONFAST considers Brazil a single subsidiary with a complex network of operations dispersed across the country. Initially characterized as a domestic geographic dispersion, the Brazilian IIN evolved to regional with the South Cone control towers at Site C1.

The autonomy each subsidiary enjoys in developing their own business and operations characterizes multi-domestic coordination for the Brazilian-led IIN. The global planning and procurement platforms, the introduction of the SAP platform at the regional level, and the control towers in Brazil indicate a tendency towards higher network integration, at least for activities like planning, procurement, logistics, quality, and maintenance. The coordination evolution faces challenges, however. In the past, CONFAST attempted to transition from multi-domestic to global coordination by using virtual sites, but the initiative failed. On the other hand, IINs enjoy more integration due to digital technologies, enabling faster communication among all plants and avoiding the duplication of efforts seen in traditional multi-domestic networks.

The Brazilian IIN has evolved from a Regional focus network to a type of Regional integrated configuration. The Brazilian subsidiary aggregates the South Cone's management activities because of its DT journey. The IIN plants increase data sharing and coordination efforts to organize DT initiatives across the network.

vi. The evolution of the plants with DT

All Brazilian manufacturing plants have proximity to the market as the primary strategic reason for their location since exports are just 5% of their volume. Although the subsidiary can carry its operation, locating each plant is a task executed together with the global HQ. The plants located in the southeast and northeast regions intend to supply these two significant markets, offering products to meet different consumers' needs.

The original main strategic reason to locate the manufacturing plant of C1 was the proximity to the market as the other plants. The strategic reason to locate the R&D center was the access to competencies and knowledge to adapt global products to local markets and develop local products. The southeast's control towers also locate in C1 because it counts with the local and regional functional leadership and has access to specific knowledge to run these operations. Therefore, the strategic reason to locate Site C1 has evolved from the proximity to the market to the access to knowledge and capabilities to run the integrated R&D center and the control towers, following the IIN Integration DT Journey.

Site C1 initially held two separate operations, the regional R&D center, and the production plant. DT Journeys of IIN and Integration combined the two sites into one.

The DT Journey of IIN Integration added several control towers that coordinate the local cluster of plants C1 to C5 and the planning control tower that coordinates the South Cone operations, including Brazil, Argentina, and Chile. The concentration of knowledge and competencies becomes the main reason to locate Site C1 that stands out as a reference for the entire IIN. Therefore, Site C1 upgraded from a contributor to a lead role in the IIN.

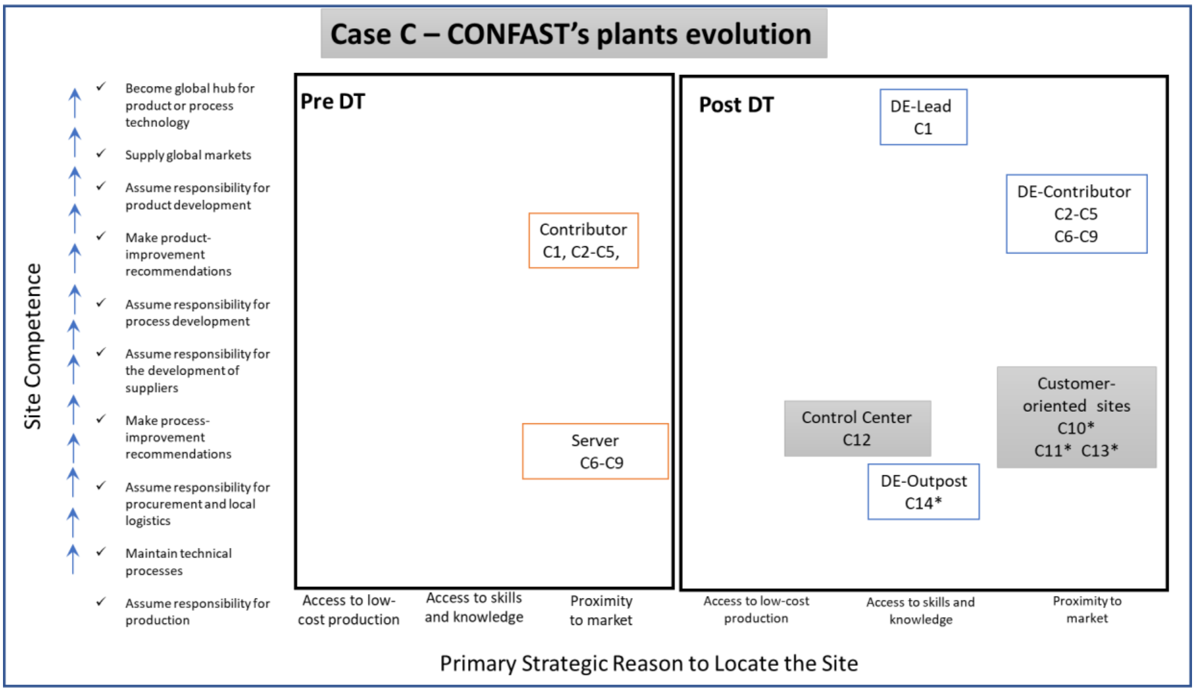
All Brazilian plants make products and develop their processes. Control towers in C1 for South-Eastern plants and C12 for the North-Eastern plants have overtaken some activities for a cluster of plants, the Brazilian subsidiary, or the Latin American region. Southeast plants C2, C3, C4, and C5, are pilots for global initiatives, consolidating their Contributor roles. The northeastern plants C6, C7, C8, and C9 also pilot DT projects with a narrower scope. Formerly Server Plants, they upgraded to Contributor Plants thanks to the IIN Integration DT journey. The quality control tower C12 coordinates activities for the four north-eastern plants. As a stand-alone operation, it would not fit in the model from Ferdows, although it plays a significant role for the IIN.

The Regional R&D center in C1 is responsible for product development using traditional tools. However, it recently has developed an innovation ecosystem C14* that counts with the collaboration of all plants in the IIN and other external partners, thanks to the DT journey of Life-Cycle Integration. C14* requires access to competencies and knowledge. Its main activity is to collect data and generate customized solutions to meet the needs of CONFAST. Their role resembles the Outpost Site from Ferdows as knowledge-collectors, but these sites also support R&D in developing new solutions and lack the production function, contradicting a base assumption in Ferdows' model.

CONFAST is increasing its participation in niche markets through M&As and joint ventures collectively called C10*, following a DT Journey of Relocation. These new operations produce for specific markets. In the model of Ferdows, sites owned by CONFAST would fit the server role, while the model would not consider JVs and partnerships. It is not clear how DT will integrate these new businesses into the IIN since this is still a very recent phenomenon.

Similarly, the DT Journey of servitization led CONFAST to join a multi-sided marketplace C13* and create the service centers C11* to the IIN, but they are still recent initiatives that deserve further research. In Ferdows' framework, C11* and C13* locate close to markets, focusing on meeting customers' needs through specific service offerings. Figure C illustrates the evolution of CONFAST's plants.

Figure C - CASE C - Evolution of the plants in CONFAST



Source: the author

Case D – POWCAP – An electrical power equipment supplier

i. Data sources

Our initial contact is the business development director of the MNE. The main primary data source was an interview session with the engineering manager, who leads the digitalization program, and the plant's operations manager in September 2019. The interviews lasted two hours. We followed up via e-mails exchanged in 2020. Other secondary data sources were the Brazilian and global company websites, annual reports and results presentations, the global investors' relations page, and a webinar at the Brazilian-German Commerce chamber.

ii. Introduction to the case

POWCAP belongs to a European conglomerate with over 170 years of existence that started actuating in by the then-nascent telecommunications sector. Today, the conglomerate is a global leader in electrification, automation, and digitalization. It operates in two hundred countries, has over three hundred thousand employees, and totalizes global revenues of over €75 billion with earnings over €5 billion. POWCAP represents the operating company in the Power and Energy sector with over seventy-five thousand employees and total annual revenues of more than €25 billion. POWCAP offers equipment for power generation, transmission, and industrial applications. The conglomerate’s leadership has recently proposed a DT strategy to introduce digital technologies into its processes and products. We investigate this strategy's developments at POWCAP and observe a site at the beginning of its DT journey.

iii. The MNE and its Brazilian operations

POWCAP is present in Brazil for over one hundred years, starting in the energy sector early in the 20th century. The Brazilian subsidiary currently counts over five thousand employees and revenues close to €1billion. The HQ in the state of São Paulo, Site D1, hosts the holding conglomerate’s corporate center, the firm's regional office in Brazil, including POWCAP in the power and energy sector, the object of this case, and DIOCO, an MNE operating in the digital services industry that we will cover in case E.

POWCAP locates manufacturing in strategic countries. The Brazilian subsidiary HQ, dubbed D1, coordinates the projects in the power and energy sector for the Brazilian subsidiary, using the manufacturing sites like D2 and the complex D3* as suppliers. Site D1 coordinates the corporate administrative functions, providing services like finance, human resources, and IT to the Brazilian operations.

The industrial complex D3* operates since the mid-1970s, hosting nine factories that produce power transformers, dry transformers, high- and medium-voltage equipment, service, and industrial turbines isolating kits, large size-frequency inverters, high-tension energy capacitors (Site D2), and products for energy control and automation. Each of the nine factories has its plant manager and operates independently from one another. Individual sites hold the autonomy to plan and execute production for their subsidiary and external clients, including other subsidiaries from POWCAP. The industry complex manages the land, installation, and utilities for all the plants, including Site D2.

The plant we visited, D2 locates inside the industrial energy complex, producing high-tension capacitors. The plant results from an acquisition in the mid-2000s that supplies external customers and POWCAP projects globally. Site D2 originally supplied capacitors to large projects demanding few products. Recently, the clients' profile changed to smaller projects, like wind and solar energy generation stations that demand a higher range of specific products. The leading market destination also shifted from overseas to domestic. This new demand profile requires higher manufacturing flexibility, driving the plant to implement an IIN Integration DT Journey seeking higher agility and flexibility.

iv. DT Strategies and Journeys

The primary DT strategy is **Integration**, given the changes in the production profile of the plant. Smaller orders with higher product variety lead to an increase in complexity for production planning and execution. The manufacturing process itself consists of production cells with little room for digitalization. The plant decided to focus on achieving work processes' vertical and horizontal integration, following an **IIN Integration DT journey**.

The DT journey in implementation at Site D2 aims to integrate systems at different levels - equipment's production logic controllers, the manufacturing execution system, and the enterprise resource planning - creating a digital twin of the operation to cope with the higher range of products and lower production volume per product type. Another initiative was POWCAP's analytical laboratory procedures automation to reduce the set-up time and improve quality checks' accuracy. An internal platform integrates R&D, production, sales, and eventually the entire supply chain. R&D engineers and laboratory operators require new capabilities to operate new digital platforms and automated systems. The new solutions impacted staff capabilities but did not affect the total headcount of the plant. Being the only site that manufactures capacitors in the IIN, Site D2's journey does not involve other plants but integrates different functions.

POWCAP recently initiated a Life-Cycle integration DT journey. POWCAP's holding conglomerate decided to introduce digital technologies into all products as part of its global DT strategy. Intelligent products allow data collection in real-time through IoT platforms, improving the management of complex systems like capacitor benches or power plants. According to our conceptual framework, the intelligent products also open the possibility to start a Digitally Enabled Servitization DT journey using the intelligent products and digital platforms, but POWCAP did not provide evidence that they intend to follow this path.

According to our informants, the DT efforts implemented so far did not produce significant organizational or cultural changes because it affects management systems, not the factory floor.

v. IIN-level evolution with DT

POWCAP's IIN concentrates operations in Brazil, although they support clients from Latin America and other regions. The plants enjoy high autonomy to manage their operations, although the HQ D1 concentrates the administrative functions and complex projects for the network. In Shi and Gregory's model, this is a hybrid Regional Focus and Global Export network. Implementing internal platforms to connect functions and systems suggests that the IIN might evolve to network coordination similar to what we observed in the previous cases. At the time of our field research, there was no observable change to the IIN configuration.

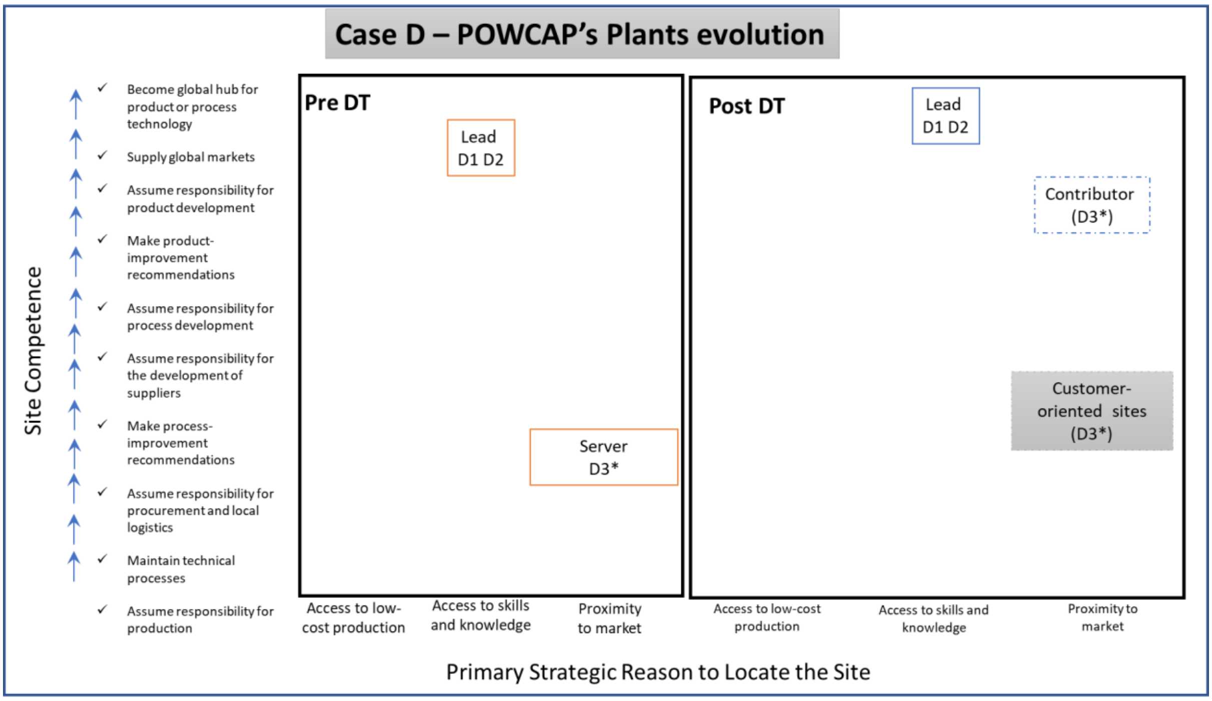
vi. The evolution of the plants with DT

Site D1 strategic reason to locate is a combination of the Brazilian market's relevance with access to capabilities to manage complex projects. Site D1 coordinates projects in the power and energy sector. The site also integrates global corporate systems and local plants by providing standard administrative services. This site does not exist in Ferdows' model since it does not manufacture products. However, it plays a central role by coordinating the plants in the IIN to deliver large and complex projects involving their products, resembling Ferdows' Lead role.

Site D2 occupies a particular position in its IIN. It is the result of the acquisition to add capabilities to POWCAP. Its strategic reason to locate is, therefore, access to knowledge and capabilities. Site D2 is a global reference in the technology of power capacitors for the MNE. Therefore, the capacitors plant D2 holds a lead role in the Ferdows' model. The DT Journey of IIN Integration confers Site D2 higher agility to cope with its customers' changing demands. The incorporation of digital technologies into the products should provide higher integration of POWCAP with other MNE's operating companies like DIOCO, the digital platform, and services provider, should POWCAP follow a Servitization Journey.

The other eight sites in the industrial complex D3* have the proximity to market as their main strategic reason to locate, but contrary to Site D2, they are not global references for their respective technologies. In Ferdows' model, they are server sites. Since they had not started DT processes during our research, they remain at a pre-DT stage. It is not clear yet if DT will upgrade them to a contributor role or remove some of their capabilities, limiting their production activities. In Figure D, we capture the two possible evolutionary paths of the cluster of sites D3*. By joining the IIN Integration DT Journey, they may upgrade to the Contributor role by leading regional or local DT initiatives. On the other hand, they could lose some of their management activities and become customized components manufacturers.

Figure D - CASE D - Evolution of the plants in POWCAP



Source: The author

Case E – DIOCO – A digital service provider for the industry

i. Data sources

Our primary contact, in this case, was the Director of Excellence on Strategy and Business. Interviews with him and the Innovation Director took place in September 2019. A second-round took place in August 2020, involving our primary contact and the Systems Engineer. Secondary sources of information included the company's Brazilian and Global websites, annual reports, results presentations for investors, fact sheets, company folders, papers, and webinars.

ii. Introduction to the case

DIOCO belongs to the same European conglomerate of firms as POWCAP in Case D. DIOCO started activities in the telecommunications sector as a supplier of equipment for telegraphs. The global digital industry operation started early in the 2000s when the automation CEO decided to sell the telecommunications operations to focus on the emerging digitalization megatrend. At that moment, the conglomerate reorganized its activities to industry, infrastructure, and energy, redirecting DIOCO to the digital services business. By then, the MNE believed that the factory digitalization would lead to a virtual factory concept, preceding the I4.0 vision from Kagermann, Wahlster, and Helbig (2013) in a decade.

A few years later, DIOCO started an M&A cycle of software companies to offer digitalization services in the entire product life cycle. New capabilities included CAD drawings, digital prototypes, planning, and production, considering the digitalization and connectivity of equipment at the factory floor. The most significant acquisition from that cycle was a company that offered solutions and systems from end-to-end in the supply chain, including product database management, computer-aided projects, and production process simulation. DIOCO started offering a closed-loop manufacturing service with continuous virtual and real-world comparison, a predecessor of CPSs. The new capabilities enabled DIOCO to offer a range of services for the digital factory. Clients can use DIOCO’s digital platforms to manage their own or their customers’ production systems.

DIOCO’s portfolio includes over five hundred digital products and services that connect over a million devices through its IoT platform. DIOCO employs forty thousand globally, with annual revenues above USD10 billion and more than twenty-five thousand employees. We selected this case because it illustrates a radical pivot from a hardware manufacturing company into a software and digital platform provider, as we detail in the next section.

iii. Global and Brazilian structure of the IIN at DIOCO

The IIN of DIOCO comprehends operations at the global and Brazilian subsidiary levels. The global HQ of the digital industries company, Site E1, is in the MNE's home country. It was formerly the global HQ for the Telecom company before pivoting from the manufacturing industry to the digital services business.

The Brazilian HQ, Site E2, is co-located with Site D1 from case D. Site E2 went through the same transformation as Site E1, from telecom to digital. We call E3* the telecom manufacturing network discontinued together with the telecom business in the 2000s.

E4* comprehends the M&As from the 2000s to develop and offer digital platforms. These companies localize in developed countries. E4* corresponds to DIOCO's R&D network.

To support the development of local solutions and build internal and external capabilities, DIOCO recently inaugurated its Service Center, Site E5, located in the industrial complex D3* from case D. Site E5 works as a training center for system users from the business ecosystem E6*. Site E5 is also a testbed for the innovation ecosystem E7* that supports the development of solutions for the local market.

iv. DT Strategies and Journeys

The **Digitally Enabled Servitization DT Journey** that led to DIOCO'S reshaping differs from a traditional servitization transformation (BAINES et al., 2020; FRANK et al., 2019) because instead of offering services related to the products that the firm already manufactures, DIOCO shifted from a telecommunications equipment manufacturer to a digital services company for the manufacturing industry. In this sense, DIOCO moved beyond the advanced servitization transformation (BAINES et al., 2020; FRANK et al., 2019).

The service offerings are flexible to meet different requirements from customers. The digital platforms from DIOCO are open to clients and developers, enabling them to build customized solutions for their markets. Clients can acquire management systems for gas or wind turbines as part of a larger project. A client may purchase the digital platforms, customize them to their use, or offer customized solutions to their customers. In either case, there is centralized platform management. Either Site E2 manages the digital services, or clients purchase the platforms and manage them for their respective clients. DIOCO'S holding conglomerate intends to incorporate digital technologies to as many of their products as possible, as we described in Case D, enabling the offering of projects using DIOCO's digital services and intelligent products from operating companies like POWCAP.

DIOCO's open platforms provide ground for a DT Journey that is simultaneously Digitally Enabled Servitization and Life-Cycle Integration involving internal partners like the acquired collection of companies E4*, local developers, and clients. Therefore, DIOCO's ecosystem simultaneously works as an innovation and business ecosystem, in line with the ecosystem definition from Adner (2006), Adner and Kapoor (2010), Gawer and Cusumano (2014), and Nambisan and Baron (2013). To support the ecosystem, DIOCO opened Site E5, a testbed connected to five other similar sites worldwide that allow the firm to integrate internal and external resources to develop optimal solutions. These centers intend to "actively collaborate in search of solutions using last generation tools and technologies like digital twins, AI, advanced analytics, and others," as described on the company's website. Site E5 represents a learning and customization center, better equipped than the Brazilian HQ E2 to provide this service, an example of the Relocation DT Journey in the services business.

From the technology dimension standpoint, the M&A cycle described in introducing this case equipped DIOCO with the right tools to offer digital services. The digital services from DIOCO support advanced digital technologies for the DT of their clients too. They use IoT to integrate equipment on the floor, IoS, to manage service offerings, CC for a shared repository to host the CPS, BDA, and AI to operate the CPS. The platforms operate at several levels, providing vertical and horizontal systems integration. Virtual and augmented reality tools support the design phase to search for inconsistencies in drawings and flow diagrams. Digital platforms and CPS configurations allow the generation of systems to monitor, forecast, simulate, and make decisions, depending on the clients' needs.

The organizational changes were the shutdown of all telecommunications operations, the M&A cycle itself, and the shift of DIOCO from a manufacturing to a services firm. Both the COO and CIO work together to eliminate competence "silos" and boost the DT process. Multifunctional teams exist in the areas of automation and DT. An advantage of the digital services from DIOCO is that they shape the cycle of a product or project through digital modeling and simulations, starting the construction of a CPS or digital twin from the cyber part of the system instead of starting from the physical part. The swap represents a significant productivity gain in developing a project because it reduces issues like physical interferences, inadequate material flows, systems under-, or over-dimensioning, as observed in case B. Another advantage is the shorter delivery time by reducing construction, assembly, and start-up times in a project. Besides, DIOCO has set partnerships with other important digital platform suppliers to enable full integration of its systems with lead systems from their partners. This way, a complete range of digital services for full vertical and horizontal integration is available in the market.

v. IIN-level evolution with DT

DIOCO pivoted from a telecommunications equipment manufacturer to a services provider to the digital factory concept. The M&As to enable the firm on digital tools resulted in a reconfiguration of activities at subsidiaries that is still in progress, integrating all units of the IIN. The global IIN's geographic dispersion from DIOCO is multinational since they have few subsidiaries offering their products and services in each region. The coordination of the IIN is multi-domestic because each subsidiary is autonomous to select service offerings and customize the solutions to its clients, although the integration of the service center E5 with its global counterparts and the R&D network suggests evolution to some type of network coordination. The current IIN does not fit any of the network types in Shi and Gregory's model (1998). Since this case involves discontinuing a network and forming a new one, we do not discuss the evolution of the IIN in this case.

vi. The evolution of the plants with DT

Although this is now a services company, we analyze case E under the lens of the model from Ferdows. This approach intends to explore the fit of the model to a services IIN. For this analysis, we consider the development of platforms and services as "R&D," the development of local support solutions as "production," and the digital platforms and service offerings as "products."

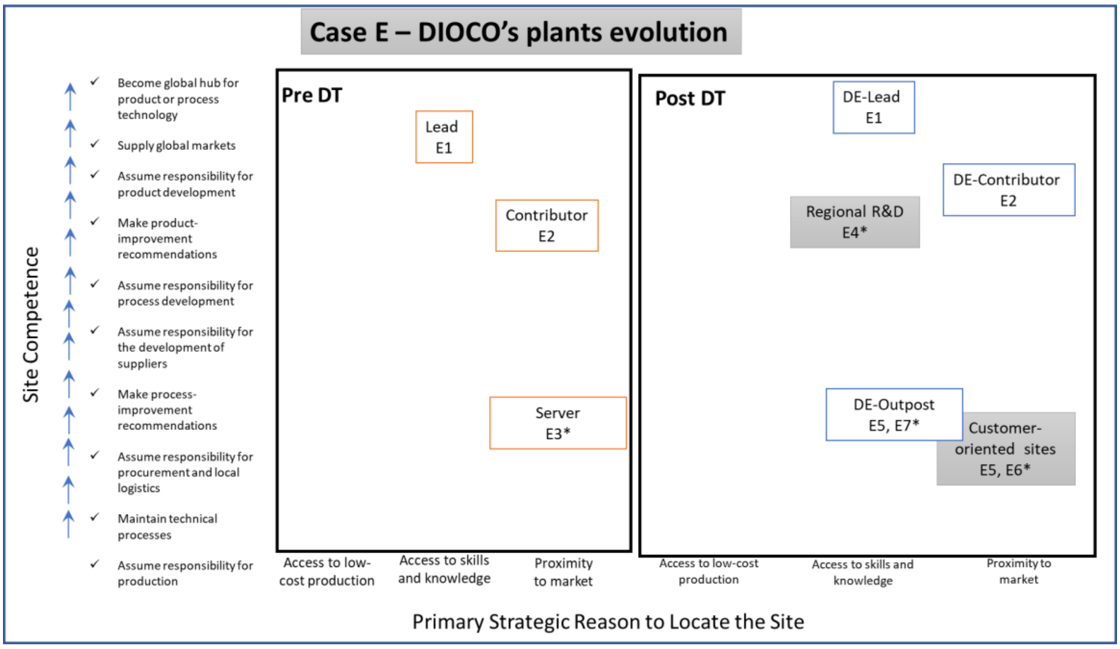
Site E1 is the global HQ in the MNE's home country, developing and offering a portfolio of standard products and service offerings. It has a lead role as it is the global reference for the company. As we have pointed in case D for POWCAP, the Brazilian subsidiary is a single-country cluster for DIOCO. The main reason to locate Site E2 with the Brazilian HQ is access to existing knowledge and capabilities. Site E2 is autonomous in selecting the platforms to commercialize in the local market, coordinates the innovation ecosystem E7* for value creation, the business ecosystem E6* for value capture, coordinates the service center E5, and contributes with E1 and E4* on assessing local market needs for other global product and service development. Therefore, Site E2 plays a Contributor role in the global IIN and a Lead role for the Brazilian subsidiary.

DIOCO shut down the former Telecom company and all its operations E3* when it pivoted its business to the digital factory. DIOCO is a digital services provider that stems from an entire servitization journey. Therefore, it does not offer physical manufactured products but digital platforms as products or services.

The M&A of many software and digital platform developers formed the network of DIOCO’s R&D centers E4*. The availability of knowledge and competencies is the driver to locate E4*.

The digital platform application center, Site E5, one of five integration centers globally, provides an environment where DIOCO, partners, and clients can co-create customized digital solutions. Therefore, DIOCO based its location on two factors, the access to qualified developers for the innovation ecosystem E7* and the proximity to the clients representing the business ecosystem E6*. The nature of the products and services, in this case, requires higher digital capabilities from developers, customizers, customers, and end-users. Therefore, Site E5 has critical roles as a customization service center that supports value capture for the business ecosystem E6* and an outpost for the innovation ecosystem E7* that creates value through developing solutions for the local market. E5 also collaborates with the other four centers worldwide and the R&D network E4* in supporting the local ecosystems. As we mentioned earlier in this section, the two ecosystems, E6* and E7*, overlap to form a single ecosystem. Figure E represents DIOCO’s IIN, depicting the ecosystems’ overlap and Site E5 as having both outpost and customization service center roles.

Figure E - CASE E - Evolution of the Plants in DIOCO



Source: The author

Case F – RING – A supplier of the automotive industry

i. Data sources

For this case, the primary data source was a site visit and interviews with the industrial director and the process, project, and services manager. Both lead the DT process at RING. The visit and interviews took place in September 2019 and lasted four hours. We collected further information via e-mails exchanged with both informants and from the company's website.

ii. Introduction to the case

RING is a Brazilian MNE that supplies the automotive industry. Its gross revenue is around €100 million per year. RING acquired operations in Argentina and Europe in the 1990s, opening greenfield operations in the USA and China in the 2000s. In 2014 RING initiated a joint venture with a Chinese manufacturer to expand China and the USA's operations. The Latin American operations became independent in 2019, consisting of two plants in Brazil and one in Argentina supplying the entire region. The Latin American IIN is the object of the current research. RING is present in two main markets, the vehicle assembly industry, and the replacement market. The vehicle industry market concentrates on few customers that require just-in-time supply, whereas the replacement market disperses in several distributors supplying the vast network of repair shops across Latin America. Repair kits, assembled with products from RING and other suppliers, are a differential that characterizes a basic service (BAINES et al., 2020).

iii. The MNE and its Brazilian operations

The IIN of this case consists of two plants in Brazil, Sites F1 and F2, and one plant in Argentina, Site F3. The current HQ in São Paulo, Site F1, was the original main production plant. Today, RING transferred all production and the company's R&D center to Site F2, located in São Paulo's interior. Site F1 hosts a separation and distribution center for the retail market, with ten days for high rotation parts and 90 days for low rotation parts. Eventually, this operation should also transfer to Site F2 because the location of Site F1 evolved from an industrial into an urban area.

Site F2 is the current manufacturing plant of RING. The production area received an upgrade with I4.0 technologies that integrated and automated the operation. The incremented production capacity achieved with I4.0 technologies enabled Site F2 to concentrate all production and R&D activities for the IIN.

The plant in Argentina, Site F3, will shut down production due to the extra capacity in Site F2. Site F3 will turn into a distribution and service center to attend the Argentinean market.

iv. DT Strategies and Journeys

RING has developed DT strategies focused on its processes, customers, and products. RING adopted an IIN Integration DT Journey concentrating efforts in the manufacturing Site F2 and integrating the network with the digital twin based on their internal digital platform SAP R3. As a result, they could increase production capacity at Site F2, integrating activities like inspection, quality, production planning, inventory, and delivery. Another outcome of this strategy was relocating all production from Sites F1 and F3 to Site F2.

From the technological perspective, the production process at Site F2 received digital technologies to integrate machines, operators, and processes, replacing manual activities. Site F2 implemented a series of I4.0 technologies, like real-time processing, machine-to-machine integration, collaborative robots for materials handling, feed, and discharge of the production presses, automated inspection machines for parts analysis, product sorting, and packaging. IoT allows horizontal integration of the manufacturing process to monitor and control environments and utilities. CC and BDA store and process data in real-time for machines, equipment, and controlled environments. These systems can take automated decisions. 3D printing technologies support quick prototyping. Another technological improvement, the SAP R3 data management platform, provides vertical integration of machine-level logical programable controllers, the manufacturing execution system, and the enterprise resource planning system. It integrates machines and processes like environmental controls, inventories, orders, scheduling, and production execution by forming a CPS digital twin. System integration occurs at all sites of the IIN, optimizing inventory levels, production, quality, environmental control, and distribution operations.

There are changes in the organization to support DT. RING reduced its workforce by about 70%, not just in production but also in other support functions like HR and procurement. Automation of manual tasks like loading and unloading presses, part inspections, and part sorting contributed to increased productivity and production reliability. RING created a technical developers' team to implement and sustain these processes and contracted a services helpdesk. Lean manufacturing tools transform the organization by optimizing activities and work processes preceding digitalization. Employees contribute to the development, digitalization, and use of solutions. To implement a DT culture, RING uses lean principles like creativity, autonomy, and consensus (Nemawashi). People trust digital systems because they prioritize, develop, and implement them according to their needs. Two examples are digital marketing and window control for order delivery systems.

R&D was a separate function at the F1 plant. It relocated to plant F2 with DT and fully integrated with production as part of the IIN Integration DT journey, responding for materials, processes, tooling, products, and supply chain digitalization. Digital tools in place are 3D printers and augmented reality for fast prototyping. The main change is organizational. R&D and production work together using fast prototyping and testing tools like A3 and Scrum. The R&D function gained agility with applied research carried by multifunctional teams. The integration goes beyond traditional product development. The process development team is now responsible for maintaining processes and machines. Inversion projects using fast development low-cost tools replaced the traditional R&D process, replacing hierarchy approval gates with monthly progress reviews. Decisions rely on the development teams now, an outstanding simplification against the traditional hierarchical formal approval processes. There is higher agility, lower expenditure, and better results.

The Life-Cycle Integration DT journey at RING intends to simplify the complex development process that involves external partners located in Europe. RING is using a digital platform to simplify the development process of its critical materials. Today, RING establishes the desired properties, an external laboratory in Germany simulates material compositions to attain the best solution, and another laboratory in the UK tests the proposed solution. The digital industry platform intends to simplify the process by reshoring most of its steps, increasing product development speed by working with Brazilian partners that join the platform, creating an innovation ecosystem F4*.

The Digitally Enabled Servitization DT journey offers a digital platform capable of supporting customers in selecting and using RING's products. The intention is to create loyalty to the MNE by forming a business ecosystem F5*. A solution that uses augmented reality is also under development to support end-users to install and service equipment.

Finally, the Relocation DT journey at RING has a similar development to Case A. The I4.0 line's increased capacity, flexibility, and agility promoted the production relocation from the other IIN plants to Site F2. The digital technologies and higher functional integration allowed Site F2 to offer customized solutions to their clients, like parts that integrate traditional seal functions with higher-order digital functionalities. Once again, 3-D printing technologies find use in product development and maintenance but not directly in product manufacturing, as foreseen in literature.

v. IIN-level evolution with DT

Our study's IIN involves the Latin American operation with a **regional geographic dispersion** in the model from Shi and Gregory (1998), consisting of operations in Brazil and Argentina supplying the Latin American market. The coordination of the IIN moved from multi-domestic to global with systems integration via SAP R3. RING evolved from a Regional Focus to a Global Exporting Manufacturing configuration (SHI; GREGORY, 1998). We did not collect any evidence of higher autonomy for foreign operations in case F.

vi. The evolution of the plants with DT

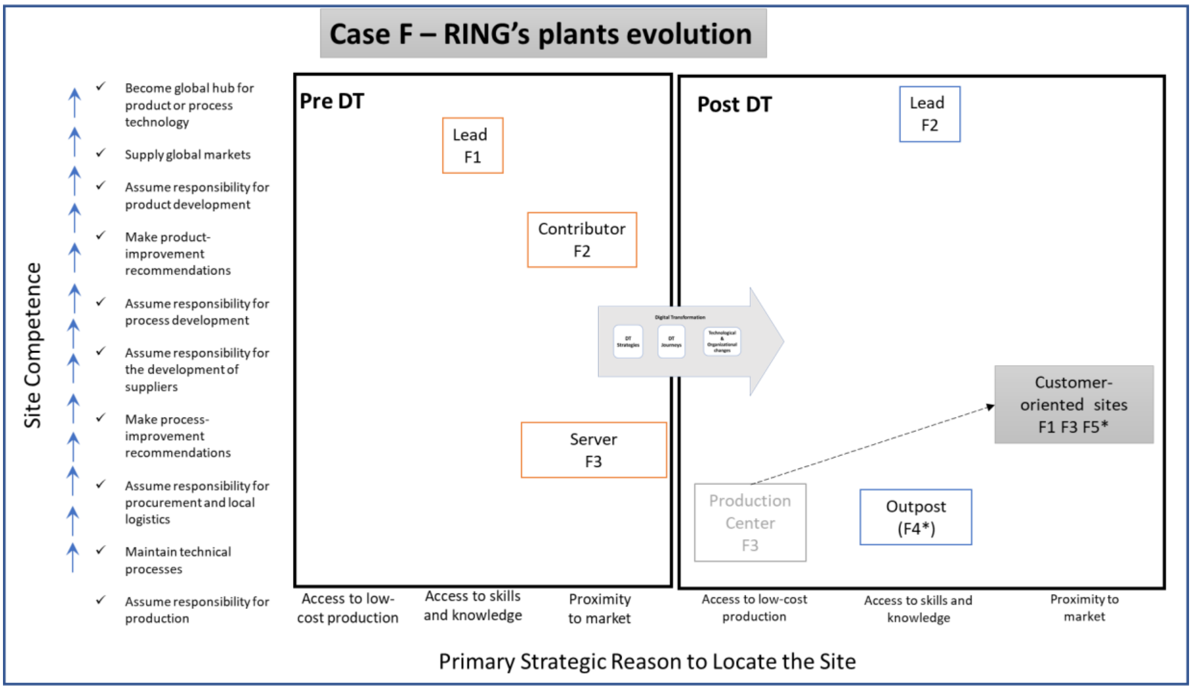
The main reason to locate Site F1 in São Paulo was the proximity to the market. However, its increasing operating cost and access restrictions make its location disadvantageous when compared to Site F2. Production and R&D activities already moved with the start-up of the I4.0 plant at Site F2. The remaining operations, storage, and distribution to the retail market not yet digitalized should move to that site soon. This evolutionary path took the F1 plant from the leader role down to a service center, a role that is not part of the model from Ferdows. Eventually, Site F1 will discontinue operations because of the high operation and DT implementation costs at that location.

Site F2 has the advantages of proximity to the large Brazilian south-eastern market and access to a central knowledge center in São Paulo's inland that supplies the plant with a specialized workforce at a lower cost than São Paulo city. Implementing the I4.0 manufacturing system resulted in a 40% reduction of occupied area and capacity to supply the Latin American demand of the MNE. Site F2 will concentrate all production from RING, as well as the R&D activity. Site F2 upgraded from contributor to lead role, thanks to the DT Journey of IIN Integration.

The original main strategic reason to locate Site F3 in Argentina was access to the local market. With the capacity increase of the Brazilian operation, the reason for maintaining that plant became the lower production costs based on tax benefits, exporting part of its production to Brazil. After Site F2 implemented DT, these cost benefits are no longer attractive. The plant will shut down its production activities and retain others like the distribution center and technical services post to the Argentinean market. Its survival stems once again from its proximity to the market. Site F3 started as a server plant in the Ferdows model, turned into an offshore with the IIN Integration DT Journey when it joined the internal SAP platform, and finally lost the production capability and became a services center.

The DT Journey of life-cycle integration originated an innovation ecosystem F4* to support RING's products' development of critical materials. The Servitization DT journey created a business ecosystem F5* intending to ensure repurchasing and brand loyalty. Figure F depicts the evolution of the IIN in Case F.

Figure F – CASE F - Evolution of the Plants in RING



Source: The author

Case G – CROP – Protecting the agro

i. Data sources

In this case, our primary contact is CROP's operations manager, who introduced us to the DT leader of the Site. The primary data source was a 2-hour interview with the plant's DT leader in 2019, complemented with e-mail exchanges and visits to the company's Brazilian, Latin American, and global websites.

ii. Introduction to the case

The current case refers to the South American subsidiary of the agribusiness sector that we name CROP. A traditional chemical European MNE actuating in the Chemical, Pharmaceutical, and Agribusiness sectors for over 150 years recently acquired CROP, formerly a North American MNE. The acquisition indicates that agribusiness is becoming more relevant in the last few years. The plant we visited, Site G1, is the leading manufacturer of a well-known brand for crop protection that sells in several different presentations. We selected this case to complement the data already collected in other cases because it involves a continuous production process, typical of the chemical industry.

iii. The MNE and its Brazilian operations

CROP counts three factories in Latin America, two of them in Brazil and one in Argentina. CROP manufactures a well-known brand of products for crop protection.

The main manufacturing plant in this IIN is Site G1, located in São Paulo, Brazil. Site G1 counts with a continuous automated process and a robotized packing line. The plant also hosts an R&D center to adapt products to the Brazilian market and coordinates the logistic network composed of several distribution centers for Brazil, dubbed G5*. The firm's DT provides the opportunity for better integration but should not change the roles of the plants in the IIN.

Site G2 in Argentina is a manufacturing plant of finished products for the Latin American market, and Site G4, located at an industrial cluster in the North East region of Brazil, makes and supplies intermediate products for the Latin American IIN. Both sites concentrate on the activity of production. A network of Distribution Centers G5* delivers the products to customers, retailers, and large farms in Brazil.

The ever-growing environmental pressures from society led CROP to form a network with several start-ups that monitor and optimize the use of chemicals in the field. Collectively named G3*, these companies use advanced digital technologies to monitor crops in real-time. There are Brazilian and foreign start-ups providing this type of service to CROP.

iv. DT Strategies and Journeys

CROP has two main DT strategies. The first one, Integration, follows a global end-to-end program to build a world-class supply chain through digital solutions using the nine digital technologies model from Boston Consulting Group (RÜßMANN et al., 2015; STRANGE; ZUCCHELLA, 2017). The second one, Servitization, intends to reduce the environmental impact of the products in the field.

CROP adopted an **IIN Integration DT journey** to improve its productivity and integrate the logistics network in line with the global integration strategy. Process plants like Sites G1 and G2 operate digitized automated processes employing third industrial revolution's technologies. Sensors and systems generate around six thousand pieces of data per minute in Site G1, an amount that the plant is not yet capable of handling without advanced digital technologies. The current focus of Site G1 is to enhance the data storage and analysis, moving from a reactive “descriptive/diagnostic” model to a “predictive/prescriptive” model in line with the advanced stages of digital maturity models. The high degree of automation in the production processes allows Site G1 to look for machine learning solutions to build a digital twin with simulation and prescription capabilities. An example of the DT project is the optimization of steam generation by three available boilers using AI. The Site formed a CPS that provides the best solution depending on variations of the plant's steam demand.

Horizontal and vertical integration of logistics systems enables Site G1 to coordinate the distribution network formed by G5* distribution centers. Previously stand-alone sites, now G1 monitors the distribution centers' inventory levels in real-time using an internal digital platform, optimizing the flow of products, avoiding excess or lack of inventory, blurring the boundaries of production and logistics operations, and enhancing the service to CROP’s customers.

In terms of organizational structure, the plant has a DT leader independent of and supported by ICT. There is also a corporate DT leader that coordinates efforts at the CROP and its holding MNE. The operations teams work under the lean philosophy, adopted since the 2000s. The DT Journey of IIN Integration adopted a productivity increase approach based on quick wins. Small incremental projects use the available data to optimize processes. The plant is looking for alternatives to acquire data science capabilities by qualifying their current employees or hiring data scientists in the market. There is no significant impact on staff, given the fact that the plant is already automated. As cultural change programs, organizational flexibility and tolerance to errors initiatives stimulate the plant's innovation and autonomy.

The Digitally Enabled Servitization DT journey focuses on better applying the products, optimizing their efficiency, and minimizing the environment's impact. The start-up companies G3* collect and analyze hydric stress and pest activity data using field sensors, IoT, satellite imaging, CC, BDA, and AI to support digital business platforms that guide the agribusiness on critical decisions for handling crops, optimizing the use of chemicals such as fertilizers and products for crop protection, thus reducing the overall environmental footprint of these products and the customers’ expenses. The economic platforms from G3* support a business ecosystem formed by these companies, customers, and CROP that uses the collected data to improve its products.

The relocation DT Journey in case G seems to have happened when the production was concentrated in automated plants using I3.0 technologies. Production relocation and the use of digital technologies improved large volume plants' productivity. There was some customization by automating the packing lines, but no evidence of digital economic platforms.

v. IIN-level evolution with DT

Before DT, the Latin American IIN had a regional geographic dispersion with autonomous plants characterizing multi-domestic coordination. After DT, the geographic dispersion remains the same, but the IIN's higher integration suggests a departure from the pure multi-domestic coordination mode. According to Shi and Gregory (1998), the IIN is evolving from a Regional Focus Network to another type of network not predicted by the model.

vi. The evolution of the plants with DT

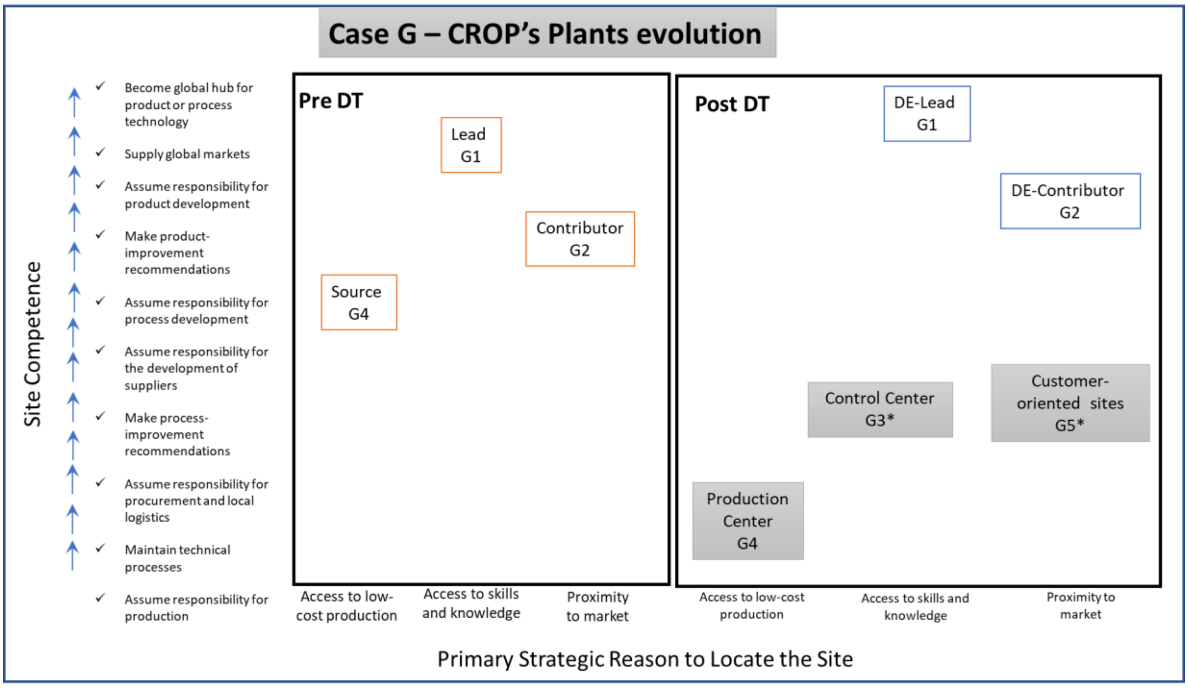
The roles of plants and distribution centers did not change significantly with DT, although there is a noticeable reorganization of the IIN. Sites G1 and G2, the two plants of the IIN that make and pack finished products, have the proximity to the market as their main strategic reason to locate. As Site G1 improves capabilities to handle digital platforms to improve internal productivity and logistics effectiveness, access to competencies and knowledge becomes more critical for the site. Site G4 locates in a petrochemical cluster in North East Brazil for cost reduction reasons, while the G5* Distribution Centers disperse to ensure proximity to the market. The start-ups G3* use digital platforms to monitor the field in real-time. The strategic reason to locate G3* is the access to knowledge and competencies to build and operate the platforms besides the analytical competencies to interpret data.

Site G1 is responsible for several activities for the IIN, like regional R&D for Latin America, production for Brazil and Latin America, and the logistics network coordination gained with DT. Therefore, Site G1 holds a Lead role in the IIN. The DT Journey of IIN Integration reinforces that role as it improves digital systems to build its CPSs and integrate the IIN. Site G2 produces for the Argentinean and Latin American markets. Originally a Server site, DT's integration should allow that site to upgrade to a Contributor site with a regional scope. However, the data we collected is inconclusive to confirm this upgrade path. Site G4 supplies intermediate products to the IIN.

Originally an offshore plant**,** DT integrated it into the logistics network led by Site G1. Therefore, it loses its logistics management capability to site G1 but gains competencies to operate the internal digital platform.

Distribution centers G5* are not part of the traditional IIN from Ferdows. Because of the DT Journey of IIN Integration, they join the network using the internal digital platform coordinated at Site G1, improving inventory levels and the agility to deliver products to customers. The associated start-ups G3* offer product optimization solutions to end-users, characterizing a Digitally Enabled Servitization DT Journey. They operate the platforms, collect, analyze data in real-time, and provide guidance to their clients. Figure G depicts the evolution of the IIN in Case G.

Figure G – CASE G - Evolution of the Plants in CROP



Source: The author