Schriftenreihe Logistik der Technischen Universität Berlin Band 43

Hrsg.: Frank Straube, Helmut Baumgarten

Anna Lisa Junge

# Conceptualizing and capturing digital transformation‘s customer value – a logistics and supply chain management perspective

Universitätsverlag der TU Berlin

Technische Universität Berlin

Anna Lisa Junge

**Conceptualizing and capturing digital transformation‘s customer value – a logistics and supply chain management perspective**

Die *Schriftenreihe Logistik der Technischen Universität Berlin* wird herausgegeben von:
Prof. Dr.-Ing. Frank Straube,
Prof. Dr.-Ing. Dr. rer. pol. h.c. Helmut Baumgarten

Schriftenreihe Logistik der Technischen Universität Berlin | 43

Anna Lisa Junge

# Conceptualizing and capturing digital transformation's customer value – a logistics and supply chain management perspective

Universitätsverlag der TU Berlin

**Bibliografische Information der Deutschen Nationalbibliothek**
Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.dnb.de abrufbar.

**Universitätsverlag der TU Berlin, 2020**
http://verlag.tu-berlin.de

Fasanenstr. 88, 10623 Berlin
Tel.: +49 (0)30 314 76131 / Fax: -76133
E-Mail: publikationen@ub.tu-berlin.de

Zugl.: Berlin, Techn. Univ., Diss., 2020
Gutachter: Prof. Dr.-Ing. Frank Straube
Gutachter: Prof. Dr. Dr. h. c. Wolfgang Kersten (Technische Universität Hamburg)
Die Arbeit wurde am 26. Juni 2020 an der Fakultät VII unter Vorsitz von Prof. Dr. Zarnekow erfolgreich verteidigt.



Druck: docupoint GmbH
Satz/Layout: Anna Lisa Junge

ORCID iD Anna Lisa Junge: 0000-0003-3415-0739
https://orcid.org/0000-0003-3415-0739

**ISBN 978-3-7983-3177-8 (print)**
**ISBN 978-3-7983-3178-5 (online)**

**ISSN 1865-3170 (print)**
**ISSN 2197-0564 (online)**

Zugleich online veröffentlicht auf dem institutionellen Repositorium der Technischen Universität Berlin:
DOI 10.14279/depositonce-10589
http://dx.doi.org/10.14279/depositonce-10589

# Table of contents

# List of Figures

# List of Tables

# Abbreviations

| | |
|---|---|
| AR | Augmented Reality |
| B2B | Business-to-business |
| B2C | Business-to-consumer |
| CPS | Cyber Physical Systems |
| CRM | Customer Relationship Management |
| DT | Digital Transformation |
| ICT | Information and Communication Technology |
| IoS | Internet of Services |
| IoT | Internet of Things |
| IT | Information Technology |
| JIS | Just in Sequence |
| JIT | Just in Time |
| KPI | Key Performance Indicator |
| L&SCM | Logistics and Supply Chain Management |
| NGT | Nominal Group Technique |
| PLM | Product Lifecycle Management |
| PPS | Production Planning and Scheduling |
| RAMI 4.0 | Reference Architecture Model Industry 4.0 |
| RBV | Resource-based view |
| RFID | Radio Frequency Identification |
| SC | Supply Chain |
| SCM | Supply Chain Management |
| SLR | Systematic literature review |
| STS | Socio-technological systems |
| VR | Virtual Reality |

# Abstract

This thesis aims to add knowledge that contributes to answering the question of how digital transformation technologies can contribute to increasing customer value in logistics and supply chain management (L&SCM), and how manufacturing companies can mindfully use them. The output of the thesis is an architectural framework that proposes performance components, approaches and methodologies that can help in capturing this customer value.

To build the basis for such a framework, this research first deduces and presents the underlying definition of digital transformation and describes its potential for, as well as current barriers for its application in, L&SCM.

The study uses a systematic literature review to identify nine underlying digital transformation technology bundles. These are: auto-identification technologies; information and communication technologies; the cloud; cyber physical systems; analytics; distributed ledger; automation technologies; augmented and virtual reality; and additive manufacturing.

These technologies served as inputs for a nominal group technique workshop aiming to conceptualize the dimensions of customer value based on the technologies. The derived dimensions are information disclosure, time, product/production, service/assistance, quality, choice options, and planning. Based on these findings, this thesis presents an impact assessment for customer-based L&SCM performance. The three-plus-one customer value propositions are availability, servitization, co-creation, and cognition as enhancement.

Expert interviews provide the data for the architectural framework for capturing customer value based on digital transformation technologies in L&SCM. The six dimensions covered are the customer value proposition; the value portfolio; scope

of collaboration; human resource management and organization; performance management; as well as the (re-)adjusting value assessment.

The main scientific contribution lies in conceptualizing the customer value for L&SCM based on digital transformation technologies whereas the architectural framework constitutes the main practical contributions.

# Kurzfassung

Ziel dieser Arbeit ist es, die Frage zu beantworten, wie digitale Transformationstechnologien dazu beitragen und bewusst eingesetzt werden können, um den Kundennutzen in Logistik und Supply Chain Management (L&SCM) von produzierenden Unternehmen zu erhöhen. Das Ergebnis ist ein architektonischer Rahmen, der Leistungskomponenten, Ansätze und Methoden vorschlägt, wie dieser Kundenmehrwert erfasst und umgesetzt werden kann.

Um die Grundlage für das Framework zu schaffen, leitet diese Arbeit zunächst die zugrunde liegende Definition für digitale Transformation ab und beschreibt deren Potentiale sowie die aktuellen Barrieren für L&SCM.

Die relevanten neun digitalen Transformationstechnologiebündel werden auf Basis einer systematischen Literaturanalyse identifiziert. Es handelt sich um Technologien zur automatischen Identifizierung, Informations- und Kommunikationstechnologien, Cloud, cyberphysikalische Systeme, Analytics, Distributed Ledger, Automatisierungstechnologien, Augmented und Virtual Reality sowie Additive Fertigung. Diese Technologien dienen als Input für einen Nominal Group Technique-Workshop, der darauf abzielt, die Dimensionen des Kundennutzens auf der Grundlage dieser Technologien zu konzeptualisieren. Die abgeleiteten Dimensionen sind Informationsverfügbarkeit, Zeit, Produkt/Produktion, Service und Assistenzsysteme, Qualität, Auswahlmöglichkeiten und Planung. Auf der Grundlage dieser Ergebnisse wird ein Einflussmodell für kundenorientierte L&SCM Leistungen vorgestellt. Die drei plus eins Kundenwertversprechen sind Verfügbarkeit, Service, Ko-Kreation und Kognition als Zusatzkomponente bzw. Erweiterung.

Experteninterviews dienen als Datenbasis für das architektonische Framework zur Erfassung des Kundennutzens auf der Grundlage digitaler Transformationstech-

nologien in L&SCM. Die sechs abgedeckten Dimensionen sind das Kundenwertversprechen, das Wertportfolio, Kollaboration, Personalmanagement und Organisation, Leistungsmanagement sowie die Erfassung und Bewertung des Kundenwertes.

Der wichtigste wissenschaftliche Beitrag liegt in der Konzeption des Kundennutzens für L&SCM auf der Grundlage digitaler Transformationstechnologien, während der wichtigste praktische Beitrag in dem architektonischen Framework zu sehen ist.

# 1 Introduction

## 1.1 Motivation

Digital transformation (DT) holds immense promise for improving logistics and supply chain management (L&SCM).[1] This evolution, which is mainly technology driven, commits manufacturing companies to moving significantly closer to the customer and using their resources more efficiently, and enables new growth potential and new business models.[2,3] This promises more effective and efficient L&SCM systems.

Internal as well as external trends are putting pressure on companies to consider DT activities. External trends include the increasing complexity of products, services, and supplier management, along with the need for digital interfaces. These are exacerbated by individual customer requirements and changing buying behavior across various channels. Competition is increasing owing to newly emerging companies built on digitalized business models. Internal trends encompass the digitalization of business processes, thereby leading to greater transparency along the value network, process optimization through data analytics, higher levels of automation, and changes in talent management and leadership. Speed and scalability are two major challenges relating to the implementation of DT projects. The pace of production and logistics is ever accelerating, reinforced by Amazon and similar providers.[4] Many companies' operations become more complex and less efficient when operating across borders. DT technologies can help to deal with complexity and hence create leaner L&SCM systems. Technologies can help to support anticipating and avoiding risks and disruptions in L&SCM networks, on the one hand, and represent an enabler for new business models on the other hand.

[1] Cf. World Economic Forum 2016, p. 4
[2] Cf. Accenture Strategy 2015, pp. 3 ff.
[3] Cf. Schmidt et al. 2015, p. 11
[4] Cf. Zillmann 2016, p. 23

However, it is still necessary to ask, what exactly is DT in logistics? Despite the increasing number of publications in this area, there is not yet any consistent widely accepted definition of this term. The terms DT, Industry 4.0, and L&SCM 4.0 lack a clear definition and are not well understood. The literature suggests that the potential of DT in L&SCM relates to the capabilities of decentralization, self-regulation, and autonomous intelligence (machine learning), but scientific publications conceptualizing the impact of DT on L&SCM are rare.[5] DT is complex and can affect many or all segments of a company. Managers often lack clarity about options and elements (e.g. technologies) worth considering for DT.[6] Alongside the increasing importance of DT, a further question arises: which strategies and concrete solutions are best suited for specific companies? One driver should be the added value expected from the implementation and use of a particular technology or technology bundle. This thesis aims at providing insights to bridge this gap by linking the use of DT technologies with customer value added. It will define and describe the impact of DT on L&SCM of manufacturing companies with a specific focus on technologies and how they can be used and implemented to create more customer-oriented processes and services, and hence create greater customer value.

## 1.2 Research objective and approach

Companies that recognize the importance of and pursue DT activities are better prepared to respond to customers' requirements.[7] Successful logistics concepts, such as lean management, just-in-time (JIT) or just-in-sequence (JIS), are customer oriented and intended to steer value creation, as far as possible, according to customers' requirements. Risks associated with DT include the unclear role of people in automated or semi-automated networks, and the degree of transparency about processes, which is most beneficial when taking into account the interests

[5] Cf. Hofmann and Rüsch 2017, p. 23
[6] Cf. Hess et al. 2016, p. 124
[7] Cf. Kersten et al. 2017b, p. 22

of all stakeholders. One reason why computer integrated manufacturing failed as a concept was the predominant focus on technology-related parameters instead of exogenous trends, human aspects and changing customer needs. The three aspects of DT are organization, humans and technologies, each of which is also influenced by the surrounding environment. Hence, successful DT endeavors need to consider these four aspects. To stay competitive, companies have to take advantage of the increasing availability of data and the possibilities that new technologies offer, while respecting the requirements of an adapted strategy, and upskill or hiring employees according to needs.[8] Impacts on employees and organizational aspects find consideration in this thesis, but the focus is on technological capabilities and effects, because the use of technologies enables improved customer relations[9] and thus represents one option for responding to the trend of increasing customer demands.[10] Therefore, this thesis aims at assessing the impact of technologies with relevance for DT concerning their potential contribution for better reacting to customer needs and increasing customer value added. The research presented in in this thesis intends to answer the following research questions:

I. How can DT technologies contribute, and be mindfully used, to increase customer value in L&SCM?

   a. What is the status quo of DT in logistics systems in research and practice, especially in manufacturing industry? What are the main challenges to implementation?

   b. What are the relevant DT technologies in L&SCM and their respective capabilities? What are the benefits and requirements, as well as the barriers and challenges, for implementing them mindfully to increase customer value?

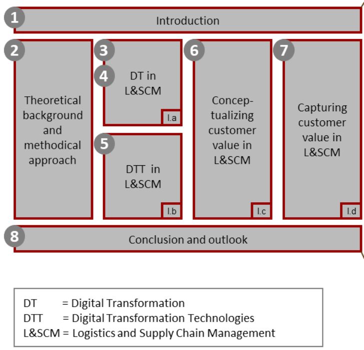
[8] Cf. Bailey et al. 2016, pp. 5 ff.
[9] Cf. Accenture Strategy 2015, pp. 3 ff.
[10] Cf. Oonk 2014, p. 2

c. How can DT technologies help increase customer value? How can these effects be conceptualized?

d. What does an architectural framework for implementing DT technologies for capturing customer value in L&SCM look like? What are the resulting recommendations for L&SCM management?

## 1.3 Thesis outline

Figure 1 shows the outline of this thesis and builds on the research questions stated above. Chapter 2.2 provides an explanation of, and a justification for, the applied research methods.




| | Secondary research questions | Method | Outcome |
|---|---|---|---|
| Describe | **Ia.** What is the status quo of DT in logistics systems in research and practice, especially in the manufacturing industry? | Literature review, Survey | Description of the status quo of DT in L&SCM |
| Describe | Ib. What are the relevant DTT in L&SCM and their respective capabilities? | Systematic literature review | Description and systematization of DTT and their capabilities |
| Explain | Ic. How can DTT help increase customer value? How can these effects be conceptualized? | Nominal Group Technique | Conceptualization of DTT's customer value |
| Design | **Id.** How does an organizational framework for implementing DTT for capturing customer value in L&SCM look like? What are resulting recommendations for L&SCM management? | Expert interviews | Validated framework for implementing DTT for increasing customer value in L&SCM |

**Figure 1:** Thesis outline

The research aim is visionary, depicting the potential of DT (technologies) for increasing customer value in L&SCM, and the nature of the research is exploratory. Therefore, an applied research approach is chosen, which can be described in terms of the following characteristics:[11]

[11] Cf. Saunders et al. 2016, p. 124

- Philosophy: Interpretivism
- Theory Building: Inductive
- Methodological choice: Qualitative
- Strategy: Survey, workshop and expert interviews
- Time horizon: Cross sectional.

To account for the characteristics above, a mixed-method approach will be applied. This comprises a literature analysis, survey, nominal group technique, and expert interviews. Chapter 2 presents and elaborates the relevant theoretical foundations.

# 2 Theoretical background

This chapter will provide information about the theoretical background of this thesis by first describing the theoretical basis and framing, and second describing the methodological approach.

## 2.1 Theoretical basis and framing

A wide range of factors has led to increasing complexity in global L&SCM. These include: scale; technological advancements; degree of customization; number of variants; quantity of delivery paths; number of feedback loops in production and delivery systems; distinct knowledge bases; skills and competencies; end-user involvement and requirements; numbers of actors in the network and extent of involvement with those actors; as well as the extent of involvement of regulators and other stakeholders.[12] The evolution of technologies – not only for supporting and improving existing processes, but as enablers for new business models – makes it essential to have a consistent innovation-embracing technology management system in place. Shorter innovation cycles in technological development and use amplify this effect. The following sections present theories with importance for DT and DT technologies in L&SCM to provide a sound basis from which this thesis can proceed.

**Resource-based view (RBV)**

The RBV proposes that the valuable, tangible or intangible, resources that a firm deploys are the basis of its competitive advantage. Those resources can be machinery, customer loyalty, production experience, human resources, or technological knowledge and/or equipment.[13] In order to sustain a competitive advantage, the resources have to be heterogeneous in nature and not perfectly mobile. This means that resources are especially valuable if they are neither perfectly imitable

[12] Cf. Cucchiella and Gastaldi 2006, p. 701
[13] Cf. Wernerfelt 1984, pp. 174 f.

nor substitutable without great effort.[14] Academic research has applied the RBV to describe a wide range of phenomena. In L&SCM this includes, for example, integration strategies[15] or green SCM.[16] Although there has also been criticism of the RBV as a theoretical frame for L&SCM, it remains prevalent and, along with dynamic resource advantage theory, a recommended basis for further research.[17]

**Socio-technological systems (STS) theory**

The origin of STS theory lies in coal-getting and it was put forward by Trist and Bamforth.[18] Social factors affect the development, implementation and use of technologies in L&SCM and therefore influence the organizational outcomes of L&SCM systems.[19] For STS in L&SCM, special consideration must be given to intra- instead of inter-organizational relationships.[20] Figure 2 depicts the relationships in STS.

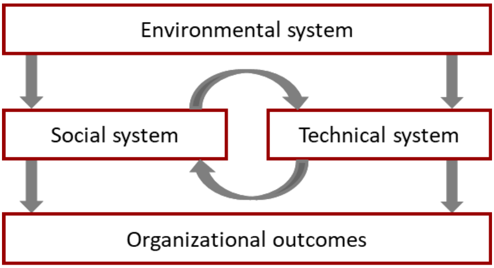



**Figure 2:** Relationships within socio-technological systems theory[21]

[14] Cf. Barney 2016 pp. 105 f.
[15] Cf. Sabet et al. 2017
[16] Cf. Savita et al. 2016
[17] Cf. Hunt and Davis 2012, p. 19
[18] Cf. Trist and Bamforth 1951
[19] Cf. Choi and Liker 2002, pp. 199 f.
[20] Cf. Clegg 2000, p. 475
[21] Cf. Kull et al. 2013, p. 67

## Contingency theory

The contingency theory claims that technologies, environments and organizations are contingent, thus suggesting a multiple-environment and multiple-technology view of complex organizations. Contingency theory evolved from socio-technical theory (see STS, above). Increasing complexity of technologies, organizations and environments leads to more uncertainty and dependence. As this complexity in environments increases, organizations must adapt their internal structure and processes in order to maintain effectiveness. Multiple technologies engender multiple environments. Fit is created by means of internal structuring and buffering. The core technology hence constrains the choice of structure. The relationship between the specific technology and structure emerges when the core technology is applied to internal fit characteristics like roles (see task-technology fit). Organizational sub-units, as well as accompanying infrastructure around the core technology, intend to control the internal environment in response to external uncertainties.[22] For an example of a multiple-environment, multiple-technology model of the firm please refer to Figure 3.

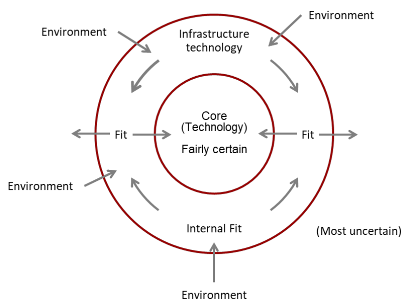



**Figure 3:** Contingency theory: a multiple-environment, multiple-technology model[23]

[22] Cf. Jelinek 1977

[23] Jelinek 1977, p. 22

**Task-technology fit**

This theory states that the performance impacts and the utilization of a technology or a technology bundle depend on the task as well as technology characteristics. The task-technology fit was originally developed and tested for information systems on an individual level and can be used to test whether they meet user needs. Underlying assumptions are that, for an information technology (IT) to have a positive impact on performance, it must be utilized and has to be a good fit for the tasks it intends to support.[24] For an elaboration about task-technology fit on the group level, please refer to Zigurs and Buckland.[25]

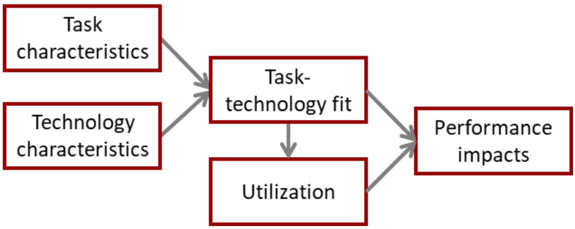



**Figure 4:** Task-technology fit: technology to performance chain[26]

**Mindful innovation**

Swanson and Ramiller (2004) state that a firm that is innovating mindfully concerning the implementation and use of IT grounds the reasons for this innovation in its own organizational facts and specifics. The larger community's organizing vision is the starting point and precedes the focus on local specifics. During comprehension, meaning sense-making efforts, of the (technological) innovation, this vision is strongly engaged in. Comprehension results in adaption or non-adaption. This is grounded in a rationale that explains the business value of the innovation as well as related barriers and challenges, and means that the firm does not have

[24] Cf. Goodhue and Thompson 1995, p. 213
[25] Cf. Zigurs and Buckland 1998
[26] Goodhue and Thompson 1995, p. 220

to be an early adopter (depending on the firm's specifics and rationale). Implementation requires know-how and know-when, and can be referred to as implementation technology management. Mindful implementation means being skeptical concerning one-size fits all solutions and therefore reinventing the innovation if necessary. Assimilation means utilization of the technology and demonstrating its usefulness (see task-technology fit). Mindfulness also sees failure as a source of learning and hence progress. A firm that is innovating mindfully has Positional (Engagement), Transitional (Commitment) and Re-positional (Achievement) attributes.[27]

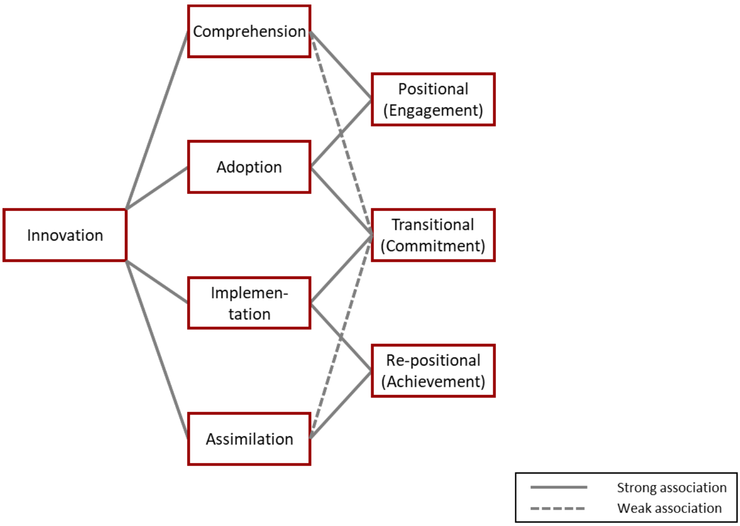



**Figure 5:** Mindful organizational innovation: its processes and intentionalities[28]

[27] Cf. Swanson and Ramiller 2004
[28] Swanson and Ramiller 2004, p. 558

## Conclusion and implications

The theories described are closely interwoven, which has the following main implications for this thesis:

- Technologies and technology bundles must be viewed in a larger context; namely, in their relation to the organizational, social and environmental system.
- Technologies are the valuable tangible or intangible resources that a firm deploys, and can constitute the basis for competitive advantage.
- Use of technologies is contingent on internal organization and infrastructure as well as on a largely uncertain environment.
- Task and technology characteristics determine the task-technology fit, which, in combination with utilization, impacts on performance.
- Firms innovating mindfully ground the reasons for this innovation in their own organizational facts and specifics.

Figure 6 summarizes and displays the interrelation of the presented theoretical framing and the structure and building blocks of this thesis.

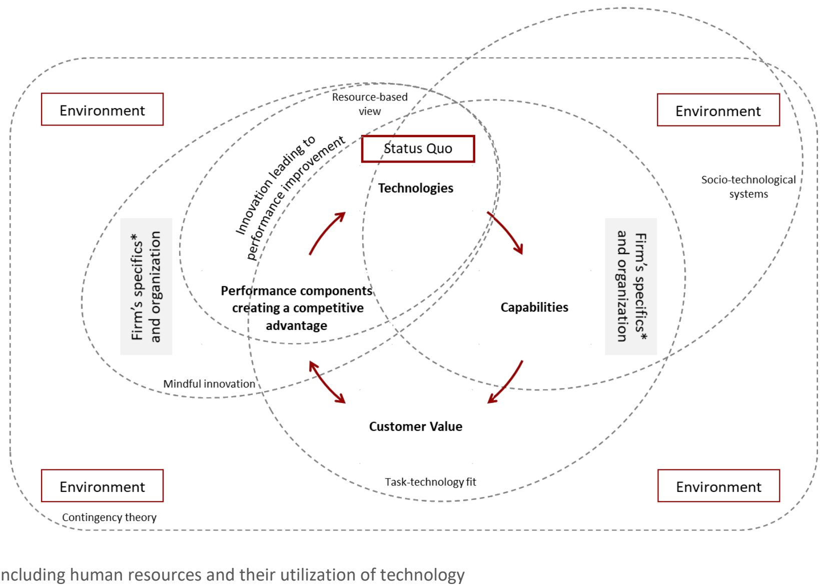



**Figure 6:** Interrelation of theoretical framing and thesis structure

The following section delineates the methodological approach to elaborating the building blocks (secondary research questions) of this thesis, building on the research characteristics described in Chapter 1.3.

## 2.2 Methodological approach

The methodological approach to answer the secondary research questions comprises a mixed methods approach. The mixed methods approach is in line with the research characteristics explained and stated above; namely, interpretivism, induction, qualitative research methods (survey, NGT, and expert interviews), and a cross-sectional time horizon. Chapters 3 and 4 lay the theoretical foundation for this thesis by providing definitional framing and reviewing the status quo of DT in L&SCM in the manufacturing industry. This is based on a review of the literature and a survey. The next chapter, Chapter 5, presents and discusses DT technologies relevant for L&SCM as well as their respective capabilities, determined by a systematic literature review (SLR). A nominal group technique among practitioners serves to conceptualize the customer value (Chapter 6). This research then builds on expert interviews to develop an inductive conceptual framework for implementing DT technologies with the explicit purpose of increasing customer centricity.

**Table 1:** Methodological approach

| Secondary research questions | Methodological approach | Chapter |
|---|---|---|
| What is the status quo of DT in logistics systems in research and practice, especially in manufacturing industry? What are the main challenges to implementation? | Literature analysis and survey | 3 & 4 |
| What are the relevant DT technologies in manufacturing L&SCM and their respective capabilities? What are benefits and requirements as well as barriers and challenges for implementing them mindfully to increase customer value? | Systematic literature review | 5 |
| How can DT technologies help increase customer value? How can these effects be conceptualized? | Nominal group technique | 6 |
| What does an architectural framework for implementing DT technologies for capturing customer value in L&SCM look like? What are the resulting recommendations for L&SCM management? | Expert interviews | 7 |

The methods will be described in the respective chapters. Overall, the methodological approach follows the structure of *describe* (Chapters 3–5), *explain* (Chapter 6) and *design* (Chapter 7). Chapter 5 provides, in the course of the SLR, a short comparison of the methodical approach chosen for this thesis and the methods applied in the reviewed articles.

The following chapter (Chapter 3) defines the terms Industry 4.0 and DT in general, as well as in L&SCM specifically.

# 3 Digital transformation in logistics and supply chain management

The aim of this chapter is to provide an overview of the evolution of the term DT, which is grounded in the term Industry 4.0, coined in Germany in 2011. There are many terms used for the fourth industrial (r)evolution: Industry 4.0, digitalization, and DT are just some of them. These terms are mainly marketing-driven; this is why a definition valid for this thesis is needed. This subchapter also intends to give a short overview of the term's history and developments in Germany and Europe, the USA, China and Japan, thereby leading to a definition of DT in L&SCM, which serves as a working base for proceeding further.

## 3.1 National initiatives

Table 2 lists initiatives, associations and impulse generators from selected countries. These mainly represent public–private partnerships for funding, and are discussed further below.

**Table 2:** National initiatives in selected countries

| Country | Name | Selected initiatives | Focus | Link |
|---|---|---|---|---|
| Germany | Industrie 4.0 | Plattform Industrie 4.0, OpenIoTFog, Industrial Data space | Digital innovation and Information and Communication Technology (ICT) market; transformation of business models and product/service delivery. | https://www.plattform-i40.de https://openiot-fog.org/ |
| France | Industrie du future | Alliance Industrie du futur | Mainly private sector funding. Support for companies to accelerate their uptake of digital technologies, to transform business models and modernize production practices. The overall objective is to address significant underinvestment adversely affecting in particular SMEs and mid-tier firms. | http://www.industrie-dufutur.org/ |
| USA | Industrial Internet Consortium | OpenFog, Advanced Manufacturing Partnership | The Industrial Internet Consortium, now incorporating OpenFog, was founded in March 2014 to bring together the organizations and technologies necessary to accelerate the growth of the Industrial Internet by identifying, assembling and promoting best practices. Membership includes small and large technology innovators, vertical market leaders, researchers, universities and government organizations. The Industrial Internet Consortium and the OpenFog Consortium (OpenFog) allied in 2019. | https://www.iiconsortium.org https://www.openfogconsortium.org/ |
| China | China 2025 | Made in China 2025<br>Internet Plus | China 2025 aims at making China's manufacturing industry more competitive. Key areas are energy saving and new energy vehicles, and high-end equipment manufacturing, including new IT and robotics, as future directions. | No English landing page available |
| Japan | Society 5.0 | Industrial Value Chain Initiative, Robot Revolution Initiative, Monodzukuri White Book, Connected Industries | Society 5.0 subsumes the various other initiatives as an umbrella. There is an existing partnership with the German Industrie 4.0 initiative. | https://iv-i.org/wp/en/ |

The term Industry 4.0 was coined in Germany. The name already expresses that the efforts behind it are directed to manufacturing industry in the narrower sense, and industry generally in the broader sense. Initially launched by a business alliance, the Industry 4.0 platform is now coordinated and driven by the government.

China is watching German efforts with interest and sees them as a model for its own development, which is being driven forward by the government under the umbrella of the strategies *Made in China 2025* and *Internet Plus*. The topic is much broader than in Germany. In addition, the Chinese economy is very heterogeneous and, in many cases, not yet at the level of German companies, which is why the Chinese strategy is, for now, geared more towards developing the country's manufacturing industry to the Industry 3.0 level.

On average, Japan's, production is much more automated than that of China; many companies are known as pioneers in their fields. However, Japan is only partially able to convert this superiority into competitive advantage. Germany's Industry 4.0 strategy is also being pursued with interest in Japan; however, its own strategy does not focus so strongly on industry. Although the *Industrial Value Chain Initiative* is an approach that focuses on production, the robot revolution is the central theme in Japan.

In the USA, the development of Industry 4.0 – in the American understanding it is more Industry 3.0, since the first two industrial revolutions are considered as one – seems less politically organized than it is in the other three countries. The Industrial Internet Consortium, which was founded by industrial companies and is also strongly driven by the economy, is taking the lead in this field, at least in the public perception. Nevertheless, with the Advanced Manufacturing Partnership, there is also a government initiative that is driving forward the topic of Industry 4.0. This is similar to the German industry 4.0 platform and concentrates on production. However, it explicitly includes materials research and the use of findings from the natural sciences.[29]

It is obvious from the various initiatives in the field that governments and industries are associating certain potentials with the evolution towards Industry 4.0 but that regulation and standardization need to be developed appropriately. There is particular focus on frameworks for cloud and fog architecture. With the *OpenFog* initiative and the *Industrial Data Space* from the USA and Germany, respectively, the competition between countries is obvious and it will be interesting to see whether there will be future alliances. The Industrial Data Space has now become the International Data Space.

It is remarkable that L&SCM is indirectly addressed by many of the initiatives but seldom represents a core stream or workgroup. As L&SCM is a discipline that is highly affected by DT, the next section provides a definitional framing.

## 3.2 Definitional framing digital transformation in logistics and supply chain management

Relating to the socio-technical dimensions, DT encompasses people, organizations and technologies plus their environment. DT can be described as an evolution (not a revolution) from digitization for creating visibility regarding (semi-) autonomous processes in L&SCM. The necessary steps are: (1) creating a digital representation of products, processes and services (digital shadow); thereby enabling (2) forecasting capability by applying data analytics; thus leading to (3) self-optimizable, adaptable production and logistics systems.[30] This increase in flexibility (adaptability, agility and alignment) is one of the major benefits associated

[29] For further information about DT initiatives in Europe, please refer to the Digital Transformation Scoreboard, available at: https://ec.europa.eu/growth/tools-databases/dem/monitor/sites/default/files/Digital%20Transformation%20Scoreboard%202018_0.pdf

[30] Cf. Schuh et al. 2016, p. 42 ff.

with DT, thus paving the way for more intelligent products, processes and services in L&SCM.

It is worth noting that DT as well as the aspired-to state of (semi-)autonomous L&SCM processes are constantly evolving concepts and visions because of changing environmental developments. The stages of DT in L&SCM can therefore be classified by, firstly, creating visibility and connectivity leading to (semi-)autonomy. The stages depend on each other and are characterized by fluid transitions as well as an increase in cognitive capabilities.

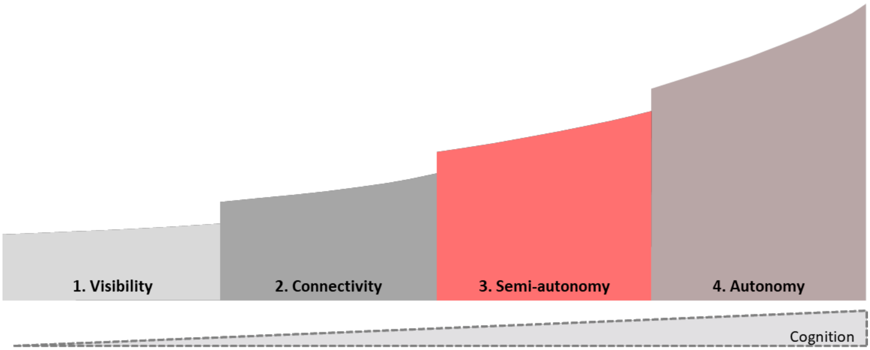



**Figure 7:** Stages of digital transformation in logistics and supply chain management[31]

For the understanding of this thesis, in a narrow definition, digitalization means the transformation of analogue data into digital data. Digital technologies, as important building blocks of DT, have three unique characteristics: (1) re-programmability, (2) data homogenization, and (3) the self-referential nature of digital technology.[32] Distinct from digital technologies as enablers of computerization and connectivity, DT technologies complement digital technologies by adding the additional capabilities of forecasting and self-optimization. These technologies are tools that form the basis for DT in L&SCM. Chapter 5 lays the foundation for

[31] Junge et al. 2019, p. 47
[32] Cf. Yoo et al. 2010, p. 726

a definition, conceptualization and discussion of the respective capabilities of DT technologies in L&SCM.

The next section gives an introduction to Industry 4.0 along with its major concepts, and this leads to a description of the enlargement of the concept's focus towards more autonomous L&SCM. The section first describes the concept Industry 4.0 and then presents the "traditional" definition of Logistics and SCM. Building on this, a definition of DT in L&SCM is derived and the prospects of this development for creating customer value are discussed.

### 3.2.1 Industry 4.0

Industry 4.0 essentially means the technical integration of Cyber-Physical Systems (CPS) into manufacturing and logistics and the use of the Internet of Things and Services in industrial processes.[33]

Key components of Industry 4.0 are CPS, the Internet of Things (IoT), the Internet of Services (IoS) and the Smart Factory.[34] CPS vertically integrate production plants and embedded devices (IoT) with business processes (IoS) and networks for human-machine communication (Internet of People).[35]

Strandhagen et al. (2017) identify three kinds of integration for Industry 4.0. First, **vertical integration,** meaning the integration of various IT systems in different layers. Second, **horizontal integration** through value networks, enabling the seamless flow of material and enhanced collaboration between all stakeholders across the L&SCM network. Third, **end-to-end engineering** across the value network, facilitating simultaneous engineering and improving product lifecycle management (PLM).[36]

---

[33] Cf. Kagermann et al. 2013, p. 9
[34] Cf. Hermann et al. 2016, p. 3929
[35] Cf. Prause and Weigand 2016, p. 106
[36] Cf. Strandhagen et al. 2017, p. 345

This study conducts a literature review as the first step in assessing the relevant core subjects for the exploration of this topic in L&SCM, . The aim of this step is to review existing frameworks and explanatory contributions relating to Industry 4.0 in order to derive a valid basis of core subjects according to which the thesis can proceed. The results are presented below. The German Industry 4.0 work group sees the potential of this initiative in the following main areas:

- **connectivity** of autonomous, sensor-based and decentralized production resources and their respective components (drives, machinery, robots, materials handling and storage technology, operating materials), including planning and steering systems through data and processes (for example, order processing);
- further **flexibility** and dynamic design of business and production processes;
- optimized **decision making**;
- consideration of **customer- and product-specific criteria** (design, configuration, ordering, planning, production, operation and recycling);
- **integration** of intelligent products providing knowledge about their production process and future use;
- value adding potential through **new services;** and
- **resource efficiency**.[37]

Hermann et al. (2016) conducted a literature review to deduce design principles for Industry 4.0 scenarios. Their research aim was to identify design principles that academics as well as practitioners could relate to. Thus, they included not only scientific literature but also business publications. After a data-based search to identification the relevant literature, the authors performed a quantitative text analysis and a qualitative literature review. The identified clusters were then validated in a workshop that applied the nominal group technique (NGT). The identified design principles are:

- **information transparency,** including data analytics and information provision;

[37] Cf. Kagermann et al. 2013, p. 5

- **decentralized decisions**;
- **technical assistance**, encompassing both physical and virtual assistance; and
- **interconnection**, covering standards, security and collaboration.

The identified design principles can be used for carrying out Industry 4.0 projects. A possible breakdown of a project roadmap consists of the creation of a common understanding of Industry 4.0; the identification and specification of Industry 4.0 scenarios; the evaluation of the identified scenarios; specification and re-evaluation of the prioritized scenario; and the preparation of the selected scenario for implementation.[38]

Hess et al. (2016) identify four key dimensions of DT, which are the use of technologies, changes in value creation, structural changes, and financial aspects.

- The use of **technologies** is displayed in a company's capability to strategically explore and exploit new digital technologies.
- Changes in value creation mean the **shift of a company's revenue streams and value creation** caused by DT.
- Structural changes include **changes in organizational structures** but also in processes and skill sets that need to be expanded and adapted in order to cope with and exploit new technologies and approaches. This also concerns the collaborations with new actors, competitors and customers.
- The last dimension, the **financial aspect**, depicts the company's ability to finance DT projects and the capability to react in response to a struggling core business.[39]

As comparing the different definitions and core aspects of Industry 4.0 and DT paradigms makes obvious, there is not yet any uniform definition and understanding. The DT term has been evolving and gaining in importance since its inception

[38] Cf. Hermann et al. 2016
[39] Cf. Hess et al. 2016, p. 124

in the year 2011. It is, however, possible to derive some overarching characteristics:

- Industry 4.0 encompasses horizontal and vertical integration as well as end-to-end engineering.
- Technologies are important enablers for Industry 4.0 and DT. They allow for transparency, connectivity and decentralization.
- Further important dimensions of Industry 4.0 and DT are organizational structures, new services and value streams, and a resulting change of a company's business model.
- The financial aspect is a prerequisite that necessarily must be involved.

From a technical point of view, the German Industry 4.0 working group developed a framework for conceptualizing the influence of Industry 4.0. The Reference Architecture Model Industry 4.0 (RAMI 4.0) distinguishes between hierarchy levels (from products, through work units and enterprises, to the connected world), layers (from assets, through information and communication, to the functional and business layer) and the value stream. The hierarchy levels closely relate to production, where Industry 4.0 originated; the value stream represents the SC and the layers refer to information and communication systems completed by the business layer. The three types of integration caused by Industry 4.0 – vertical integration, horizontal integration, and end-to-end engineering – relate to the layers, value stream and hierarchy levels of RAMI 4.0. RAMI 4.0 serves to dismantle tasks and processes into manageable components. This facilitates targeted discussions about standards and reveals where they are still missing. Furthermore, RAMI 4.0 enables the location of Industry 4.0 and DT use cases and relationships, and the definition of superordinate rules.[40]

Industry 4.0 requires the reorganization of value creation processes and disintegrates traditional industry boundaries. Important challenges to be addressed are

[40] Cf. Adolphs et al. 2015

infrastructure and standards, data security, and reskilling of employees.[41] The focus of Industry 4.0 moves from the smart factory to the value network. The following section introduces research and explanatory approaches for DT in L&SCM and links these to this chapter's discussion of Industry 4.0, thus resulting in a definition of DT in L&SCM.

### 3.2.2 Logistics and supply chain management

In order to derive a definition of DT in L&SCM, the definitions of DT, "traditional" L&SCM, and interpretations of DT in L&SCM serve as pillars. Larson and Halldorsson[42] present four perspectives concerning the relationships among the definitions of logistics and SCM. These are: traditionalist, re-labeling, unionist, and intersectionist. The literature in English literature shows a trend towards the relabeling view, which involves replacing the term logistics with SCM. This thesis will make use of the term L&SCM to account for both definitions, thereby aiming at offering a holistic perspective.

[41] Cf. Hofmann and Rüsch 2017, p. 24
[42] Cf. Larson and Halldorsson 2004

**Table 3:** Definitions of logistics and supply chain management

| Source | Definition of L&SCM |
|---|---|
| Straube (2004) | Process-oriented logistics comprises **planning, steering, execution, and control of all information and material flow within and between companies and from customers to all suppliers and sub-suppliers, as well as other value-adding partners**. Companies' logistical performance is crucial to increasing market share and securing economic results by **fulfilling customer expectations**.[43] |
| APICS (2008) | "[…] *that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption* ***in order to meet customers' requirements****.*"[44] |
| Cristopher (2011) | "[…] *logistics is* […] *an* ***integrative concept*** *that seeks to develop a system-wide view of the firm. It is fundamentally a planning concept that seeks to create a framework through which the needs of the marketplace can be translated into a manufacturing strategy and plan, which in turn links into a strategy and plan for procurement. Ideally there should be a* ***'one-plan' mentality within the business which seeks to replace the conventional stand-alone and separate plans of marketing, distribution, production and procurement.*** *This, quite simply, is the mission of logistics management*."[45] |

L&SCM is about the integrative planning, steering, execution, and control of the flows of materials, goods, and information in value-creation networks. The ultimate goal is to serve the customer the best way possible. New technological solutions can help to bridge the gap between isolated planning islands, which is also reflected in the subsequent interpretations of DT in L&SCM.

[43] Cf. Straube 2004, p. 31
[44] Cf. Blackstone 2008, p. 74
[45] Christopher 2011, p. 12

**Table 4:** Interpretations of digital transformation in logistics and supply chain management

| Source | Interpretation of DT in L&SCM |
|---|---|
| Moser et al. (2016) | Increasing use of sensors and the **connectivity** of products, processes, and services is the basis for DT and leads to new functionalities of products and services and to a visualization of the whole SC.[46] |
| Bogner et al. (2016) | *"...digitalization is seen as the **integration and optimization of information and the flow of goods along the supply chain**. The main basis for this is a consistently digitalized data flow without media discontinuities along the entire value chain of a company."*[47] |
| Korpela et al. (2017) | **Collaboration in digital SC is a multi-stakeholder endeavor** with different needs and goals. Big companies are seen as hub organizations and do the integration work together with their suppliers.[48] |
| Xue et al. (2013) | *"... we consider supply chain digitization ... as the extent to which the focal firm adopts digital supply chain systems **to transact electronically with its suppliers and customers**."*[49] |
| Hofmann and Rüsch (2017) | "*Products and services are flexibly connected via the internet or other network applications like the blockchain (consistent connectivity and computerization). The **digital connectivity enables an automated and self-optimized production of goods and services** including the delivering without human interventions (self-adapting production systems based on transparency and predictive power). The value networks are **controlled decentralized** while system elements (like manufacturing facilities or transport vehicles) are making **autonomous decisions** (autonomous and decentralized decision making). With respect to logistics management, Industry 4.0 is expected to achieve opportunities in terms of decentralization, self-regulation and efficiency.*"[50] |
| Bowersox et al. (2005) | "*True supply chain excellence will only come from making a digital business transformation. It's a transformation that exploits all that **technology** has to offer, facilitates supply chain **collaboration**, and leads to new levels of operational excellence. More than a one-time project, the transformation is a journey... .*"[51] |

[46] Cf. Moser et al. 2016, p. 71
[47] Bogner et al. 2016, p. 16
[48] Cf. Korpela et al. 2017, p. 4182
[49] Xue et al. 2013, p. 330
[50] Hofmann and Rüsch 2017, p. 25
[51] Bowersox et al. 2005, p. 22

| | |
|---|---|
| Kersten et al. (2018) | DT in L&SCM describes the change of value creation processes through the **use of technologies**, adjustment of corporate strategies, as well as the acquisition of required competences and qualifications. DT objectives are increases in flexibility, productivity, and **customer focus**.[52] |
| Straube (2017) | "*Through the use of **intelligent technologies, data analytics** and the emergence of **new actors and business models**, smart logistics is evolving into flexible, low-interference, decentralized and real-time self-controlling processes with cognitive capabilities. The automation and integration of intelligent objects and their physical and organizational interfaces with the inclusion of semi-autonomous systems becomes possible. Logistics' goal of a transparent, synchronous, and coordinated cooperation of value creation partners from legally and economically independent companies and the internal organization to **satisfy customer expectations** becomes possible.*"[53] |

The interpretations of DT in L&SCM clearly highlight the important role of technology in supporting and facilitating integration and collaboration in value networks based on increased connectivity. This increased connectivity is the basis for prospective decentralized decision-making and an improvement in efficiency. However, as DT in L&SCM is an evolving research area and there is no clear definition yet, the interpretations presented can be considered as building blocks and it is suspected that the capabilities of technologies are more extensive than simple integration and decentralization. Based on the presented characteristics and definitions of Industry 4.0 and L&SCM, this section thus provides a working definition for DT in L&SCM.

## 3.3 Definition of digital transformation in logistics and supply chain management

Concerning DT in L&SCM, the main opportunities lie in flexibility and efficiency based on new capabilities such as visibility, integration, and decentralization. In

[52] Cf. Kersten et al. 2017a, p. 51
[53] Straube 2017

the following discussion, this thesis argues that there are certain capabilities enabled by DT technologies that can help to design L&SCM networks in a more customer-oriented way to enhance the customer value created by L&SCM. However, the term smart logistics (or DT) in L&SCM remains vague. Building on the previous elaborations and on already developed explanations for DT in L&SCM, this subchapter will provide a definition that is valid for the further progress of this thesis. Before coming to the definitions, however, a brief presentation of the characteristics of both traditional and digitally transformed L&SCM is helpful.

### 3.3.1 Traditional logistics and supply chain management characteristics

The status quo of technology uptake for manufacturing companies is described in detail in section 4.1. An assessment of manufacturing performance in 2012 showed that manufacturing companies have potential for improvements in flexibility, production costs, and delivery capability. The average manufacturing performance of 65.9 % highlighted that there is still a lot of improvement potential.[54] An analysis seven years later (2019) shows that 43 % of best-practice manufacturing companies already have measures in place to provide adaptive capacity,[55] and 71 % provide real-time visibility.[56]

For a long time, professionals have recognized network-wide cost and coordination focus, a long-term perspective, and the importance of being able to adapt quickly as key L&SCM characteristics. Sharing and monitoring of information, as well as joint planning, are crucial.[57]

Currently, state practitioners in L&SCM acknowledge the need to adapt their organizations and innovation approaches in order to provide the groundwork for the future degree of autonomy in L&SCM networks, which still needs to be defined.[58]

---

[54] Cf. Grosse-Ruyken et al. 2012, p. 13
[55] Adaptive capacity is the capacity of a system to adapt if the environment, where the system exists is changing.
[56] Cf. Junge et al. 2019, p. 11
[57] Cf. Cooper and Ellram 1993, pp. 16 ff.
[58] Cf. Junge et al. 2019, p. 51

Moreover, non-integrated planning islands, both inter- and intra-organizational, still hinder the development of end-to-end data-driven services.

To overcome these challenges, studies have identified the subjects of DT in L&SCM, the organization of the future, and L&SCM as value as important fields on which to focus.[59] Technologies can be an answer to the trend of extremely flexible production concepts tailored to individual customer requirements in terms of product diversity and rapid product range changes. Those rapid changes place high demands on L&SCM in terms of response times and performance.[60]

### 3.3.2 Digitally transformed logistics and supply chain management characteristics

With the increasing volume of L&SCM processes because of distributed production sites and more complex delivery networks, there are also greater demands on the ability to identify, locate and control logistical objects such as goods, containers, operating resources, or people. There is a need for real-time, automated monitoring of L&SCM and transport processes, and telematics technologies for identity verification, localization, and status recording are available. These technologies significantly increase the transparency of L&SCM and production processes, enabling providers to control them more efficiently. In case of problems or errors in the processes, it is possible to react in real time.[61]

The real potential of DT in L&SCM lies in the improvement of forecasts, timely (real-time) intervention to reach a defined target state (for more robust planning results) and clarity about the value of interdependencies for generating customer value, for example, predictive maintenance. This leads to self-optimization through flexibility on process, organization, and technology (interoperability) lev-

[59] Cf. Kille and Meißner 2016, p. 19
[60] Cf. Zanker 2018, p. 149
[61] Cf. Schenk 2015, p. 245

els. Concerning technologies, in order to communicate among each other the subsystems need to be compatible and have to react automatically and autonomously to changes.[62]

This vision requires data in high resolution. This new data availability will allow L&SCM systems to be integrated in production planning and scheduling (PPS), thereby enabling a model-based decision basis for steering. Prerequisites for a sound decision basis for planning tasks are consistent master data and, eventually, up-to-date movement data. Real-time feedback about work processes in production – started, progress, or completed – allow for statements about progress and current system workload. These data are directly implementable in L&SCM systems and can help to organize, for example, procurement and return processes or container management in a better way. In addition, a flexible dimensioning of safety stocks becomes feasible. Although high data quality supports optimizing L&SCM systems, the degree of data granularity required must be considered.[63] For further prospects of DT in L&SCM for manufacturing companies, please refer to section 4.3.

All sectors in L&SCM can see opportunities from DT; 73 % of companies rate these as high or very high. Half of the companies, however, are waiting until the solutions are tested and have proven their value before implementing them. This attitude is inconsistent with the necessity for rapid innovation in the digital era. DT affects all aspects of L&SCM strategy. Current IT infrastructure is approaching its limits and is often insufficient for interorganizational data exchange, especially real-time data exchange. Transport-related data exchange is already quite advanced, whereas there is still potential regarding inventory, demand, and material flow disruptions. This new data influx and usage poses new challenges for employees and requires new skills. Upskilling is important but so is fostering a

[62] Cf. Schuh et al. 2016, pp. 40 ff.
[63] Cf. Nyhuis et al. 2014, pp. 90 ff.

culture of experimentation and intra-organizational entrepreneurship. As the end customer is seen as the most important driver of DT, future innovation aspirations should open the innovation process to enable novel forms of integrating customers into the idea generation and implementation process. Changing distribution channels towards platforms lead to smaller-scale and more customer-specific logistics services. This might threaten conventional business forms with the loss of access to end customers.[64]

Despite the system autonomy desired, planning is still required. Management structures have to be adapted to account for increasingly decentralized, more granular information management. This necessitates standardized planning information across the L&SCM network based on clearly defined roles and rights. More intelligent IT solutions support human planners in drawing the right conclusions for planning processes in L&SCM. There is a high potential advantage from deploying DT technologies to increase transparency and information quality in L&SCM. This also brings new requirements for organizational adaptability. Today's structures provide for centralized decision-making instead of deciding locally in a fast and flexible manner. The resulting implications for the organizational structures in L&SCM have not yet been analyzed sufficiently,[65] but there is unanimity that DT will dissolve organizational silos to enable cross-divisional collaboration.[66] There is disunity among L&SCM experts about data gathering for automated decision-making on a tactical level; 60 % disagree that automated decision-making replaces employees of the middle management, while 40 % are undecided or agree.[67]

[64] Cf. Kersten et al. 2017b, pp. 11 ff.
[65] Cf. Akinlar 2014, pp. 13 ff.
[66] Cf. Heistermann et al. 2017, p. 8
[67] Cf. Junge et al. 2019, p. 50

Bowersox et al. summarize this development, stating: "*The digital business transformation is about leadership because it affects all levels of the organization across the extended supply chain.*"[68]

Figure 8 depicts the changes that are materializing in L&SCM. These changes are affecting not only entities, but also value networks. Relevant for this research are technologies, data-driven services, and the fact that customers are the most important source of innovations and ultimately drive DT. Leadership and organizational structures should enable a mindset that facilitates DT and a focus on customers that should drive the development of new services and business models.[69]

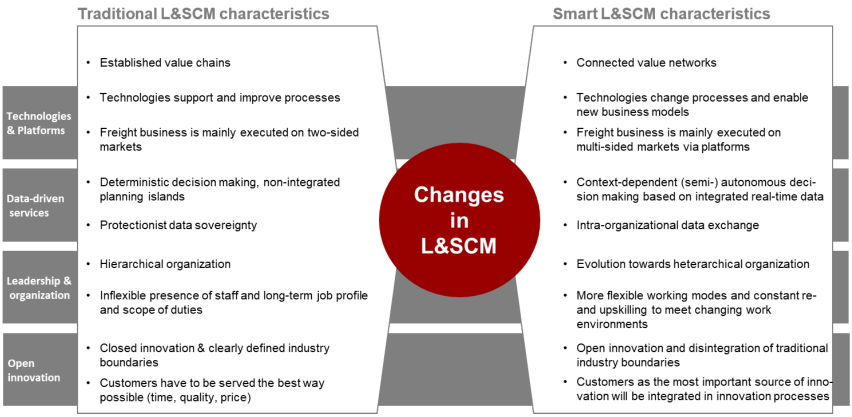



**Figure 8:** Paradigm shifts in logistic and supply chain management[70]

It is essential to capture the benefits that technology has to offer, but the enabling ecosystem – including leadership, human resource and innovation management, as well as the financial system – needs to be developed accordingly for a successful DT.

Based on the previous elaborations, DT in L&SCM is defined as follows.

[68] Bowersox et al. 2005, p. 26
[69] Cf. Bowersox et al. 2005, p. 22
[70] Junge et al. 2019, p. 47

**Digital Transformation in Logistics and Supply Chain Management is the change in value creation enabled by existing and new technologies, adaptation of business strategies based on data-driven processes and services, and the creation of a supporting ecosystem. Its goal is to achieve increased flexibility, collaboration, efficiency, and customer value, ultimately leading to (semi-) autonomous execution of tasks and optimization in value networks.**

### 3.3.3 New customer value proposition

Important aspects of this definition include the increased customer value and that the customer is the most important driver of DT. Important criteria for new solutions therefore include offering performance components that have clear and positive impacts on the customer's own value-creating process.[71]

New connectivity among L&SCM stakeholders allows for new business model patterns, based, for example, on platform-based approaches.

Fleisch et al. (2014) argue that new IT-influenced business models follow three trends. The first is the integration of users and customers into value creation. This could mean integrating them in the development phase, but could also involve delegating production tasks of, which can lead to increased collaboration. Examples of relevant business models are Open Source (content) and Mass Customization.

The second trend is service orientation. Moving closer to customers means that more interaction with them also allows for tailored services, for example, related to after-sales digital contact with customers. New interaction forms allow for differentiated service offerings. Exemplary service model offerings are Rent instead

[71] Cf. Christopher 2016, p. 35

of Buy, Subscription, Freemium, Razor and Blade and Add-on.[72] New information about customers promises a foundation for a more granular L&SCM segmentation based on customer requirements and product characteristics.[73]

The third trend is making sense and use of the increasing amount of available data. These data can represent a key asset for product design, pricing, and sales structuring. Related business models are Subscription, Flat Rate, Freemium, Pay-per-Use, and Performance-based Contracting business model patterns.[74]

All three trends directly relate to customers and this thesis follows the assumption that this also has implications for customer-based performance in L&SCM based on DT technologies.

Therefore, Chapter 6 will provide a detailed conceptualization and description of a proposed use of DT in L&SCM for increasing customer value wherein the focus lies not on the resulting business models, but on the performance components creating increasing customer value in L&SCM.

## 3.4 Summary

DT will change L&SCM characteristics. To shed light on the constituents of this transformation, this thesis focuses on the customer value enabled by existing and new technologies attributed to DT. Following the working definition of DT in L&SCM defined above, Chapter 4 depicts the status quo of technology uptake in the manufacturing industry; Chapter 5 defines the relevant technologies (DT technologies); and chapter 6 conceptualizes DT technologies' customer value in L&SCM. Subsequently, Chapter 7 proposes an architectural framework and the components necessary to implement DT technologies for increasing customer value in L&SCM.

[72] Cf. Fleisch et al. 2014, pp. 3 f.
[73] Cf. Schrauf and Berttram 2016, p. 14
[74] Cf. Fleisch et al. 2014, pp. 3 f.

# 4 Manufacturing companies' digital transformation status

This chapter intends to give an overview of the industry structure and of its implementation status and the use of DT-related technological concepts in L&SCM. Therefore, the chapter presents and discusses three different data collections: Fraunhofer, ZEW, and TU Berlin. It presents practical examples of how DT projects in L&SCM are already being implemented. Furthermore, this chapter highlights barriers to DT projects and concludes by delimiting the research field of this thesis.

## 4.1 Status quo

Recently, the numbers of publications concerning DT as well as Industry and L&SCM 4.0 have significantly increased, but valid representative scientific research is still scarce. Opinion pieces often seem to be dominated by companies seeking consultancy work. To build a solid foundation for this thesis and to enable a holistic overview, the chosen approach is to present and compare  figures about the diffusion of DT technologies. Practical examples, presented in section 4.1.1, enrich the literature findings.

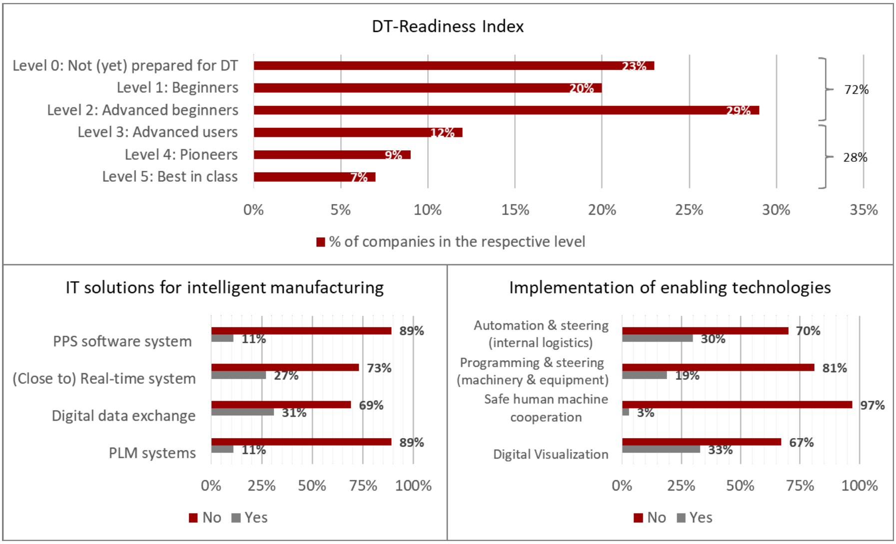
**Fraunhofer Manufacturing Survey**

The Readiness-I4.0 module of the industrial benchmark of Fraunhofer ISI is a data collection exercise from 2015 that enables companies to compare themselves to others via benchmarking. The results help companies to exploit untapped potential in the fourth industrial revolution to identify their ability and willingness to concrete implementation (readiness) of Industry 4.0 and, if necessary, introduce improvement measures for further steps towards responding to the challenges of Industry 4.0. The benchmark is based on Fraunhofer ISI's 2015 representative company survey "Modernisierung der Produktion" (modernization of production). A tailor-made benchmark group can be selected from a database of more than 1,300 manufacturing companies. This enables company-specific comparisons with area-specific groups. One of the benchmarks available is that for Industry 4.0, which focuses on nine indicators in three dimensions:

- software orientation for intelligent production
  - IT-based production planning
  - Close to real-time production control system (e.g. manufacturing execution systems)
  - IT system for SCM
  - IT system for PLM
- process-oriented technologies for intelligent production
  - IT-based steering of internal logistics
  - Mobile/wireless programming of machinery
  - Safe human–machine cooperation
  - Mobile/wireless access to work instructions
- investments in production machinery and equipment
  - Scope of investment for machinery and equipment.[75]

Figure 9 shows values representing data from 1,282 manufacturing companies in southern Germany.

[75] Cf. Fraunhofer ISI 2015




| | |
|---|---|
| DT | Digital Transformation |
| IT | Information Technology |
| PPS | Production Planning and Scheduling |
| PLM | Product Lifecycle Management |

**Figure 9:** Manufacturer's digital transformation readiness and technology deployment[76]

The numbers show that 72 % of German manufacturers are not yet prepared or are beginners concerning DT. One third of the companies use IT solutions and technologies for digital data exchange and digital visualization. PPS and PLM software systems are to be found in every tenth company and only 3 % of the companies implement safe human–machine cooperation. These numbers show that the groundwork for DT has, in many cases, not yet been laid.

[76] Cf. Fraunhofer ISI 2015, pp. 5 ff.

## ZEW Research study

A research institute for labor market research polled German companies about their use of technologies. The result was a representative survey among 2,032 German production and service companies. Technologies are classified according to Industry 1.0/2.0, 3.0, and 4.0. Industry 1.0/2.0 technologies are manual and not IT-supported; Industry 3.0 technologies are controlled indirectly and IT-supported; whereas Industry 4.0 technologies are self-optimizing, autonomous, and IT-integrated.[77]

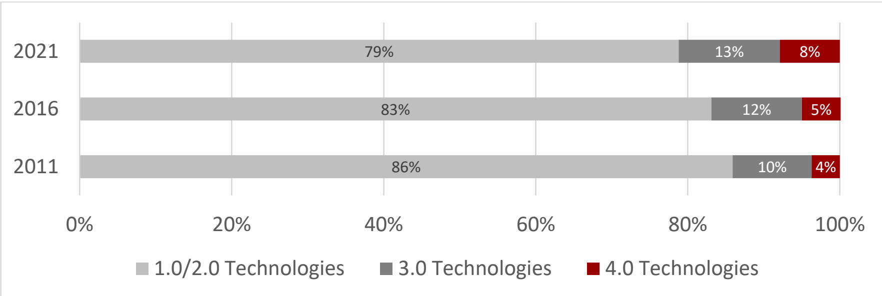



**Figure 10:** Proportion of production work equipment by technology level over time[78]

The findings of the ZEW study confirm the picture drawn by the Fraunhofer study: many companies have not yet invested in DT technologies. There will be only a moderate increase until 2021. Across all industries, the percentage of use of 4.0 technologies for 2016 is highest in retail and business-related services. Electronics, automotive, transportation, and service industries are expected to experience the strongest growth in terms of the proportion of Industry 4.0 technologies as part of the capital stock. The authors stress that their data implies a polarization of technology pioneers and (late) followers. Companies having previously invested in new technologies are also the ones who will invest in 4.0 technologies in the coming years. Pioneers are mainly bigger companies with at least double

[77] Cf. Arntz et al. 2018, p. 17
[78] Cf. Arntz et al. 2018, p. 21

the employee numbers and many times the revenue of (late) followers. Furthermore, investing companies are mainly those from the tertiary service sector that are offering new technologies themselves. This highlights the potential for producers and developers of Industry 4.0 technology.[79]

**Technische Universität Berlin Research Study: "Pathway of Digital Transformation in Logistics"[80]**

The data presented in the following paragraphs were gathered in the course of a survey for the research study "Pathway of Digital Transformation in Logistics." This study investigated the approaches of logistics experts regarding challenges such as increasing speed, integrating real-time information, reducing media discontinuities and fragmentation of systems, as well as finding approaches for cooperation with new actors such as start-ups or tech companies. The research study elaborates the topic's technologies, data-driven services, leadership, organizational structures, and open innovation.

In the study, 120 international logistics experts completed an online questionnaire. The respondents represented the following sectors: logistics service providers (37 %), industry (32 %), retail (14 %), IT and technology providers (9 %), and others such as academia and consulting (8 %). Of the participating manufacturing companies, the distribution was as follows: consumer goods (n = 15, 38 %), automotive (n = 8, 21 %), chemicals (n = 7, 18 %), machinery (n = 7, 18 %) and electronics (n = 2.5 %).[81]

The analysis of the status quo of technology use showed that around 50 % of companies already had solutions in place for connectivity and automatization; 72 % already had solutions for real-time visibility. In contrast, the implementations for adaptive capacity (32 %) and cognitive technology (23 %) were respectively

[79] Cf. Arntz et al. 2018, pp. 17 ff.
[80] Cf. Junge et al. 2019
[81] Cf. Junge et al. 2019, pp. 3 ff.

lower. This implies that companies were already laying the basis for self-optimizing processes. Close to 60 % were not planning to invest in cognitive intelligence. Compared to the other sources, this study reported a more advanced implementation status for DT technologies.[82]

**Table 5:** Implementation status of digital transformation technologies[83]

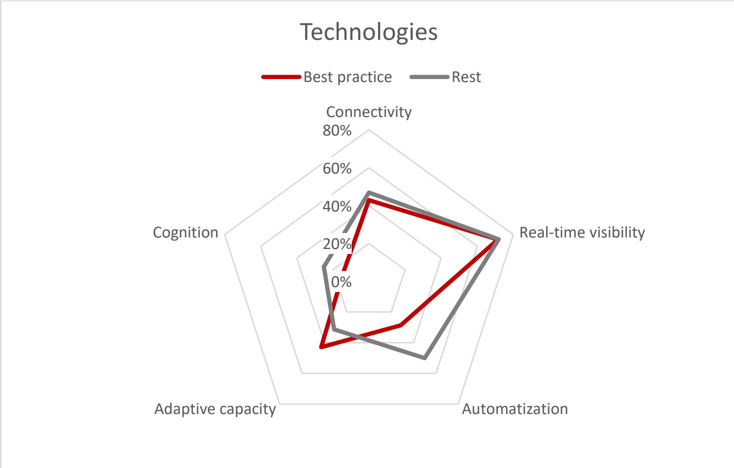
| Manufacturing Industry | **Connectivity** (e.g. sensors, beacons) | **Real-time visibility** (e.g. track & trace) | **Automatization** (e.g. autonomous vehicles, robotics) | **Adaptive capacity** (e.g. outsourced cloud services) | **Cognition** (e.g. machine learning) |
|---|---|---|---|---|---|
| **Already operational** | 26 | 51 | 26 | 28 | 18 |
| **Pilot phase** | 21 | 21 | 21 | 5 | 5 |
| **Planned for the upcoming two years** | 8 | 10 | 18 | 13 | 18 |
| **Not planned** | 45 | 18 | 36 | 54 | 59 |

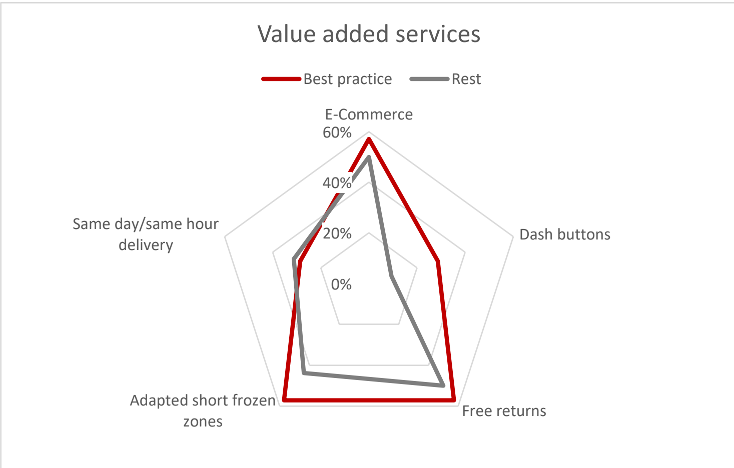
(in % of responses, deltas to 100 % are due to rounding, N = 39)

In an analysis of best practice, the study assessed key performance indicators (KPIs), which are delivery time, delivery reliability, delivery flexibility, and out-of-stock time; the best quintile of participating companies serves as the best-practice sample. Note that all KPIs are equally weighted, hence the best practice sample represents the best mean values. In a subsequent step, the research performed an analysis of the status quo of technology implementation, classified as “already operational” or “pilot phase”, that compared companies belonging to the best-practice sample with the rest. Figure 11 shows a synthesis of this analysis. It stands

[82] Cf. Junge et al. 2019, pp. 8 ff.
[83] Cf. Junge et al. 2019, p. 10

out that the best-practice sample is, to a greater extent, using connectivity technology and solutions for adaptive capacity. This allows for more flexibility. Autonomy enabled by artificial intelligence such as machine learning (cognition) so far plays a minuscule role. The use of apt ICT solutions for real-time visibility shows the highest diffusion among both the best practice companies and the rest. Connectivity and transparency are the cornerstones of DT initiatives, so the companies are preparing for more advanced solutions that enable autonomous processes. It must be considered that the sample is relatively small, with n = 39.




- BP = Best Practice (companies were analyzed by assessing four KPIs (delivery time, delivery reliability, delivery flexibility and out of stock time), the top quintile serves as BP sample)
- % shows numbers of companies having already implemented digital transformation technologies or value added services ("already operational" or "pilot phase")
- N = 39

**Figure 11:** Implementation status of digital transformation technologies and services[84]

[84] Cf. Junge et al. 2019, p. 11, p. 17

The best practice analysis shows that it is not the implementation and use of DT technologies that distinguishes best practice companies from others, but the services and processes that are offered based on the technological capabilities. This supports the theory of mindful innovation. In the evaluation of the value-added services, it is particularly hybrid service bundles such as dash buttons that differentiate best-practice companies from the rest. These hybrid service bundles offer concrete added value for customers. For business model innovation based on smart product service systems, please refer to Mittag (2019).[85]

The three presented sources describing the status quo of the use of DT technologies surveyed different panels (German manufacturing firms, German companies from all sectors, and international logistics experts) but cover a similar observation period, 2015–2017, including retrospective and prospective analyses in the case of the ZEW research. Summarizing the findings, it can be concluded that companies are slowly building up their technological portfolios to lay the basis for more advanced and autonomous solutions and processes. The best-practice analysis and the ZEW research show that the use of advanced technologies has a positive impact on performance. However, many companies are still reluctant to apply DT technologies and exploit their full potential.

The following section presents specific practice examples illustrating DT in manufacturing companies from a L&SCM perspective.

**Applied practice examples**

This section briefly presents examples that are neither exhaustive nor comprehensive in their coverage of every aspect and process of L&SCM of manufacturing companies. They are intended to give an insight into what manufacturers are already doing to digitally transform their L&SCM and into which solutions exist.

[85] Cf. Mittag 2019

**Original Equipment Manufacturers**

Mercedes-Benz Manufacturing Hungary

In the Mercedes-Benz manufacturing plant in Kecskemét, Hungary, numerous Industry 4.0 projects are being implemented to improve visibility, support communication, simplify and automate processes, utilize forecasts and big data, and increase effectiveness. Concrete examples are wheel-assembly transport with driverless transport vehicles from plant to plant, transport of the body assembly stages within the production plants and using shopping baskets for controlling complexity in assembly. In addition, the company is implementing preventive maintenance, paperless order management, online communication, a process-oriented logistics structure, no shelves in assembly bays, only shopping baskets, and a forklift-free factory. The driverless transport vehicles drive 360,000 km per year for parts supply alone. This leads to open spaces in production that can be used as social areas, thus resulting in short distances for employees to travel. In addition, technology is used consistently for digital shop floor management, right up to pick-by-light for zero defects. The latest project is the use of shopping cards for material. The plant has become a think tank that showcases test applications for the production network.[86]

Local Motors

Local Motors co-creates vehicles and drones in microfactories. The principle is to involve customers as users as early as possible in the creation process for vehicles in order to design them in a user-centric way. The vehicles or drones are then produced in micro-factories, thus leveraging innovative production technology. In 2014, Local Motors launched the world's first 3D-printed car, the Strati. The

[86] Cf. Seith 2018

company demonstrates the benefits of direct digital manufacturing to create completely customizable vehicles. In 2016, this resulted in the world's first cognitive autonomous shuttle, the Olli.[87]

Siemens

Siemens Digital Logistics was created in 2018 to strengthen Siemens positioning for DT in L&SCM. It is a merger with the cloud-specialist AXIT and the software and consulting company LOCOM. They offer a logistics platform (AX4) for collaboration and visibility in SC networks with currently 300,000 users. It offers simulation and optimization of logistics processes via a digital twin of the SC (Supply Chain Suite) and an excel-based calculator for transport cost calculations, route planning and location optimization (XCargo).[88]

**Technology and software suppliers**

The following paragraphs present some exemplary technologies that are already on the market.

In supply, new approaches for relocating sourcing closer to customers can be observed.[89,90] Additive manufacturing for products or (spare) parts is one characteristic of this development.[91] In addition, new data-driven services for, for example, preventive quality assurance and demand forecasting facilitate sourcing but also lead to smaller order batches and thus increase risk. Further exemplary prospects of advanced analytics lie in negotiations and auctions, vendor management and tactical procurement planning.[92] Software for demand forecasting promises a forecast accuracy of 95% (Blue Yonder/JDA).[93] Audi uses geofencing for the early detection of upstream late arrival in the SC, thus triggering appropriate risk

[87] Cf. Local Motors
[88] Cf. Siemens
[89] Cf. Bubner et al. 2014, p. 6
[90] Cf. Schmidt et al. 2015, p. 12
[91] Cf. Durão et al. 2017
[92] Cf. Innamorato et al. 2017
[93] Cf. JDA 2019

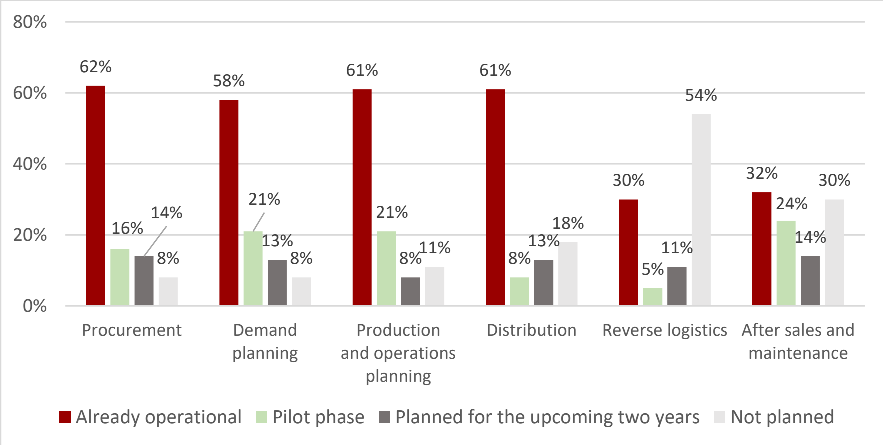
mitigation measures.[94] These examples show that advanced manufacturers already have connected inbound solutions in place.

For production, various application examples exist. For example, augmented reality (AR) permits the display of information for users where needed: in the user's field of vision and on the respective object[95] and is applied in particular on production lines and in warehouses. Smart 3D scanning solutions facilitate dimensioning, identification, and inspection. In combination with analytics solutions, complex visually-oriented tasks can be automated.[96] Robotics for automatization in multi-variant series production are already an integral part of the production process, thus freeing human capacity from repetitive tasks. New forms of collaboration, AR, robotics and semi-autonomous processes for production and L&SCM processes require coordinated interfaces and consistently integrated data.[97] Integrated data improve the coordination among production plans, production supply, warehouse management, and fleet analysis. The technology and service company Bosch uses self-developed solutions such as the *ProCon* program for production control and the disposition of internal transports. In more than 50 plants, synchronous data exchange and networking of digital process steps enable bookings, re-orders and, for example, adjustments to Kanban circuits to be made automatically in real time. Inventories and manual activities are reduced.[98] Even though China is promoting unmanned factories,[99] in reality it is much more likely that existing technology will coexist with humans and will support them in production and L&SCM processes. Therefore, new skills are needed.

An important prerequisite for drawing on the potential of DT in L&SCM is mastering supply chain analytics.

---

[94] CF. Roth 2016
[95] Cf. Jost et al. 2017, pp. 153 ff.
[96] Cf. Aquifi 2019
[97] Cf. Blümel 2013, p. 12
[98] Cf. DVZ 2018
[99] Cf. Ackerman 2015




N = 37

**Figure 12:** Application status of supply chain analytics in manufacturing companies[100]

The status quo of the application of supply chain analytics across the SC shows that around 60 % of manufacturing companies already apply data analytics in procurement, demand planning, production and operations planning, and distribution. Areas with generally untapped potential are reverse logistics, after sales, and maintenance.

The main problems across the SC are media discontinuities, which require some means to bridge the gap between different data formats and ICT solutions. Currently, both original equipment manufacturers and software providers create platforms as hubs for data integration and interface management. Examples are *Axoom* by Trumpf, Siemens *Mindshere*, the *Logistics Interface* by Jungheinrich, *Predix* by General Electric and the SAP *Cloud Platform Internet of Things*.

Technical core elements of platforms for horizontal collaboration are data, a federal structure, openness to ICT systems, a modular hard- and software structure,

[100] Cf. Junge et al. 2019, pp. 15 f.

and a reference architecture. Data can be inventory, tools, materials, mobile resources, machinery and equipment, employees, intelligent robots, as well as complete factories. The federal structure enables assuring the protection of knowledge and intellectual property. Federal character in relation to platforms means that the platform, its services, and applications can be used by different users for cooperative activities (each user has its own context). There will only be the necessary data exchange. Openness refers to accessibility via service buses or application programming interfaces for ICT systems such as Customer Relationship Management (CRM), enterprise resource planning, manufacturing execution systems, and CPS. A reference architecture can be based on RAMI 4.0. The vertical layers from assets to businesses help in classifying data and information.

Trust and acceptance are core elements of platforms. This touches transparency, communication and participation, including rights and obligations. Prerequisites for acceptance are use, an appropriate business model, as well as security and trust as described by the task–technology fit theory. Potential members of those platforms are customers, app providers, service and software providers, platform operators, and IT and basic service providers.[101]

## 4.2 Challenges of digital transformation in logistics and supply chain management

Existing challenges in L&SCM of manufacturing companies can be classified into general challenges and challenges related to specific technologies.

Concerning the general challenges in the information flow in the L&SCM network, a diverse array of variants causes a high degree of complexity for sales and operations planning. Many suppliers remain unconnected via electronic data interchange. Heterogeneous markets and customer requirements intensify this. An-

[101] Cf. Diemer 2017, pp. 181 ff.

ticipation of customer demand is difficult as the customer relationship mainly focuses on the customer order process itself. Material and requirements planning is complicated and can be impacted and disrupted by internal or external risks. Cost pressure leads to reduced inventory levels, thus further increasing susceptibility to risk. In many cases, existing master data is not available at the quality required to represent a valid source for analytics to improve L&SCM. Different distribution approaches and differences among logistics service provider capabilities impede holistic distribution planning.

As shown in section 4.1. DT-related challenges in manufacturing companies are characterized by a low uptake of potentially available technology solutions as well as a low to medium level of diffusion of the application of analytics in the different stages of the SC. In addition, the low degree of automation and of networked, standardized, value-added processes means that autonomous processes across L&SCM networks are not yet practicable, which is also shown by the fact that that, currently, interorganizational data exchange is not yet seen as a necessary competitive advantage.[102] Many organizations also struggle with providing the required leadership and management qualifications that are important enablers for successful DT.

## 4.3 Prospects of digital transformation in logistics and supply chain management

The goal of DT technologies deployment is to move towards self-organizing, flexible L&SCM systems. The definition of flexibility adopted for this thesis is as follows: Flexibility encompasses agility, adaptability, and alignment of SC, also called *triple-A SC*.[103] That is, to gain sustainable advantage, companies' L&SCM networks need to be agile, adaptable and aligned.

[102] Cf. Junge et al. 2019, p. 40
[103] Cf. Lee 2004, pp. 104 ff.

Agility means the ability to respond rapidly to short-term demand or supply changes and to manage external disruptions smoothly. Real-time information is essential to achieve agility.

Adaptability refers to adjusting the SC design to react to market shifts (structural) and to adapt the existing network to strategies, products and technologies. Such shifts occur because of economic progress, change in the political or social dimension, demographic development, or technological evolution. The adaptation of IT-systems to respond to new market requirements belongs to this category. Prerequisites are the ability to spot trends and the capability to change SC networks. To retain the option to alter L&SCM networks, companies need to develop suppliers' existing complementary systems and ensure that product design team knows the SC implications of their designs.

Alignment focuses on creating incentives for better performance by aligning the strategic orientation of all actors along the value chain. The first step is the alignment of information to have equal access to forecast and sales data, and plans. Alignment of identities follows to enable the alignment of incentives. This leads to maximizing SC performance while maximizing profit.[104]

The following paragraphs delineate a possible scenario of autonomous L&SCM in manufacturing companies.

The manufacturing planning and control system needs to adapt continuously to internal changes (company environment, strategy) and external ones (customer requirements and new market opportunities).

Many production processes are based on JIS delivery to ensure receiving the required goods at the right place and the right time in the right quality to be able to seamlessly progress with production. An interruption in the SC therefore poses a

[104] Cf. Lee 2004, p. 105

severe risk and is associated with high costs. In combination with increasing product variants and more demanding customer requirements, this requires concepts to enable efficient production in a batch size of one. Decentral, flexible, and autonomous L&SCM processes from supplier to customers can enable this efficient production. The end-to-end focus for the deployed solutions is especially important as, for example, JIS delivery and automated quality inspections need to be assessed with regard to their impact on the whole L&SCM network.

Inside the factory, a self-learning system dispatches production orders between the production lines and reacts flexibly to system failures and capacity, energy consumption, and customer priorities. Autonomous transport vehicles secure material supply and communicate via sensors with the warehouse and production systems via the cloud. These autonomous (or partly human-assisted) autonomous systems are smart objects. Their intelligence allows them to negotiate orders, routes, and pick-up locations. If small batches are produced, the conditions change accordingly, with a higher frequency. Warehouses are enabled to track inventory. When falling below safety stock the warehouse automatically re-orders. Information systems are integrated to allow for a seamless transition, both from supplier to manufacturer and from manufacturer to customer or retailer. The final products are equipped with intelligence and represent hybrid service bundles able to automatically install updates, provide additional services to their users, and provide the manufacturer with information about usage and condition. This sets new challenges with regard to data sovereignty and data security. Transportation outside the factory is automated, including loading and unloading, and intelligent routing systems based on advanced analytics assure resource and time efficiency. Autonomous transport can adapt to peaks without the restrictions of working time and protection arrangements. This allows for new location planning for customer-oriented production, for example, production close to the point of sale, which results in on- or nearshoring of production activities previously transferred abroad.

Those developments open new avenues for value creation and for new entrants into the value creation network.

As production and L&SCM are increasingly merging, their dynamics and conditions are also increasingly connected and dependent. Solutions will be built and executed on new and existing platforms, and new providers will enter the scene. They offer matchmaking, data integration, or the provision of smart services and will grow in importance. As the product is equipped with intelligence, L&SCM paradigms will change: L&SCM planning follows or is directly linked to the product, thus meaning that planning can be done in real-time and that the context is more dependent on the individual product itself. The value added for stakeholders is the flexibilization of production, shorter delivery times, and better capacity utilization.

New value-added services based on process and condition monitoring data can be a new revenue stream for manufacturers. Those services exceed the traditional value that manufacturers offer to their customers, that is, product availability. Either the manufacturer or platform and service providers will offer such services. This can result in an "app store" for value-added services in a manufacturing environment. If new actors act as service providers, they are the link between manufacturer and customer. This has a decisive impact on value creation. Customers will increasingly differentiate products according to their inherent services. Therefore, it is very attractive for manufacturers either to provide a platform or to offer services on a third-party platform. Customers benefit through an increase in offer and the relation between customer and manufacturer can be strengthened.[105]

[105] Cf. Anderl et al. 2016, pp. 12 ff.

It remains an open question whether DT in L&SCM leads to more or less robust networks. Increasing transparency, on the one hand, offers a better basis for planning and proactive risk management. On the other hand, information systems become more complex and vulnerable.

As shown in section 4.1, manufacturing companies can build the technological basis for DT in L&SCM but face several challenges with regard to technology uptake, the high number of variants, and insufficient data quality and availability. This hinders collaboration along the end-to-end L&SCM network, the integration and management of differences among logistics service providers' capabilities, and the ability to account for heterogeneous customer requirements.

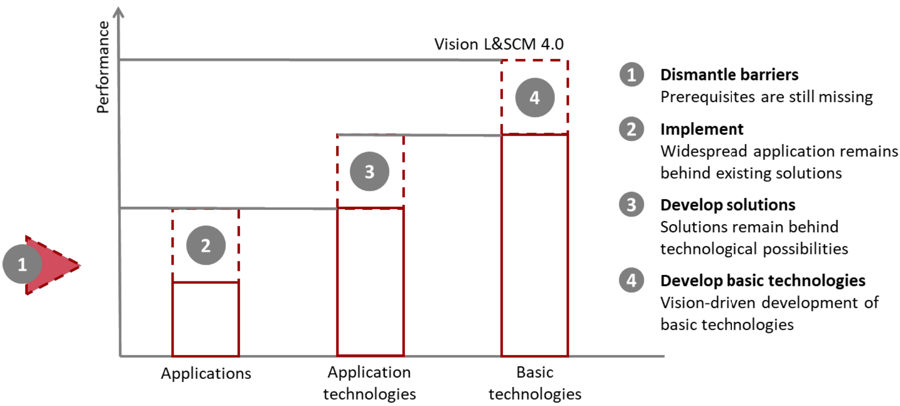



**Figure 13:** Requirements for achieving technology diffusion[106]

The basic technologies, such as sensors and actuators, are quite mature. However, end-to-end horizontal and vertical integration is still a vision. Exemplary applications exist but insufficiently connected value creation processes, lack of qualified personnel, and inadequate electronic and cloud-based data interchange hamper integration. This especially concerns small and medium enterprises.

[106] Cf. Gausemeier et al. 2016, p. 72

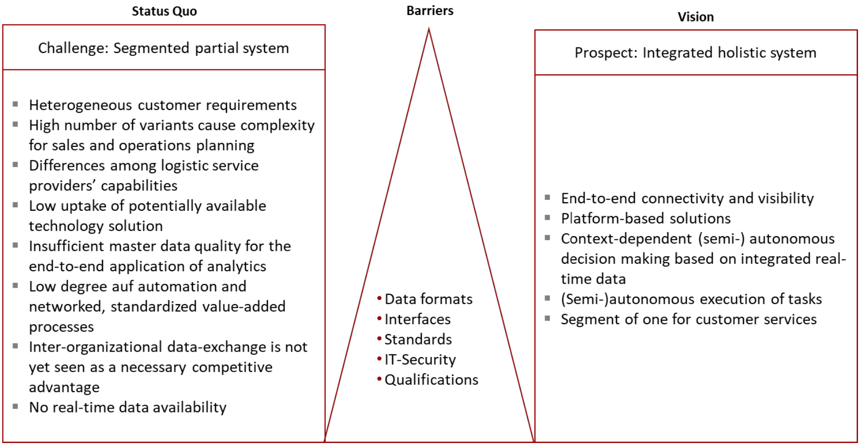



**Figure 14:** Challenges, prospects and barriers of digital transformation

Although it is desirable, SCs will not become totally integrated in the near future.[107] Promises of end-to-end connectivity and visibility are hampered by existing barriers in the areas of incompatible data formats, lack of interfaces and integration of ICT systems, and concerns about IT security. Therefore, standardization attempts are necessary. The platform Industrie 4.0 is driving standardization for Industry 4.0. They are proposing the RAMI 4.0 standard, which integrates all elements and IT components in a layer and life cycle model and divides complex processes into manageable packages, which include data protection and IT security.

The reference architecture can be regarded as a model pattern, that is, as an ideal model for the class of architectures to be modelled. Industry 4.0 does not specify a single, prescribed architecture in RAMI 4.0, but only a framework with minimum requirements. These include the definition of concepts and a methodology with rules to describe the physical world with the purpose of reflecting it in the world of information. The methodology of describing all assets of an Industry 4.0

[107] Cf. Junge et al. 2019, p. 48

solution with RAMI 4.0 makes it possible to describe an asset sufficiently precisely to create an "informatic mirror image" of it for the information world.

The actual status of L&SCM is driven by mastering the challenges of keeping pace with cost volatility, increasing visibility, risk management, increasing customer demands, and globalization. Despite the need for customer interaction, companies focus more on collaborating with their suppliers than with their customers. Concerning product development, 80 % of companies design products with their suppliers but only 68 % with their customers. Concerning SC planning, 53 % include input from their customers, in contrast to 63 % who include input from their suppliers.[108] However, this thesis does not focus on technology development and diffusion but on the potential customer value-added owing to DT technologies and on exploring how the customer value added enabled by DT technologies can be conceptualized and what strategies are needed to increase customer-centricity in an exemplary three-stage L&SCM network. The following section describes the unit of analysis, the processes, and the network within the scope of the thesis.

## 4.4 Delimitation of the thesis

This thesis focuses on the focal producing firm, which represents the characteristics described in the previous section, and its suppliers and customers. The thesis' focus on this part of the value network meets the needs to focus on inter-organizational aspects in L&SCM. Increasing connectivity of products and processes allows the linkage of machines and production lines to value-creation networks. This affects the end-use and after-sales, providing opportunities for manufacturing companies to create hybrid solutions encompassing new services. The figure below shows the value chain inherent in this thesis, which is based on Mentzer et

[108] Cf. Butner 2010, pp. 24f.

al.'s definition of a direct SC consisting of a supplier, focal firm (manufacturer), and customer.[109]

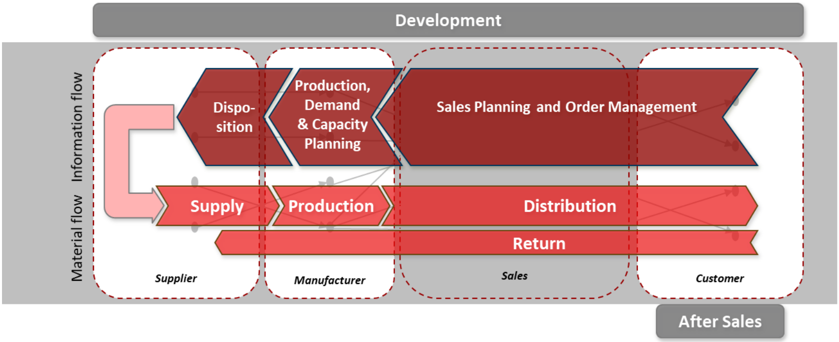



**Figure 15:** Direct supply chain of a manufacturer

The unit of analysis is manufacturing companies that are producing physical goods in-house with their own manufacturing machinery. They supply a specific customer group (either B2B or B2C) and procure from different suppliers. In addition, they use technology to support their L&SCM and production processes and have distinct structures enabling them to analyze those processes.

As stated previously, multi-variant manufacturers face several problems concerning the management of increasing complexity. At the same time, advanced planning and steering systems based on technical solutions would help in mastering this complexity. Series manufacturing is an elementary type of production that results from the characteristic of process repetition. In series manufacturing, larger but limited quantities of different products (or product types) are produced one after another in batches or in parallel on the same production lines.[110] Annual

[109] Cf. Mentzer et al. 2001, pp. 4 f.
[110] Cf. Voigt 2018b

quantities in series production are typically in the range of 1,000 to 100,000. Typical batch sizes in series production lie between 10 and 1,000.[111] Table 6 displays the characteristics of multi-variant series production.

**Table 6:** Characteristics of multi-variant series production[112]

| Typological feature | Characteristic 1 | Characteristic 2 | Characteristic 3 | Characteristic 4 | Characteristic 5 |
|---|---|---|---|---|---|
| **Range of products** | Products according to customer specification | Typecast products with custom variants | Standard products with variants | Standard products without variants | |
| **Structure of products** | One-part products | Multipart products with simple structure | Multipart products with complex structure | | |
| **Order type** | Make-to-order based on individual orders | Make-to-order based on blanket orders | Make-to-stock | | |
| **Demand type** | Sporadic | Fluctuating/ seasonal | Progressive | Linear | |
| **Vertical integration** | Low vertical integration | Medium vertical integration | High vertical integration | | |
| **Supply type** | External procurement to a low extent | External procurement to a greater extent | External procurement to a large extent | | |
| **Disposition type** | Order-based | Predominantly order-based | Predominantly plan-based | Plan-based | |
| **Type of production** | Fixed position manufacturing | Workshop production | Group or line production | Flow production | Autonomous swarm organization for production and assembly |
| **Type of assembly** | Fixed position assembly | Group assembly | Row or line assembly | Flow assembly | |

| | | |
|---|---|---|
| Exclusive or predominant characteristics of multi-variant series production | Typical characteristics of multi-variant series production | Industry 4.0 characteristics of multi-variant series production |

To overcome the challenges described in sections 4.2 and 4.3, a clear ontology and reference architecture is required to assess and describe the impacts on information layers (vertical integration), the value stream (horizontal integration), and the automatization dimension (end-to-end engineering). As previously described,

[111] Cf. Eversheim 1989, p. 11
[112] Based on Dürrschmidt 2001, p. 21

RAMI 4.0 offers such an ontology and a reference for mirroring the physical and information-technical world. As RAMI 4.0 has a clear focus on the smart factory, the inherent product lifecycle that accounts for the value stream in the architecture model is replaced by the value chain in the focus of this thesis (refer to Figure 15). The assessment within the presented frame enables categorizing the influence of technological solutions within the three different dimensions.

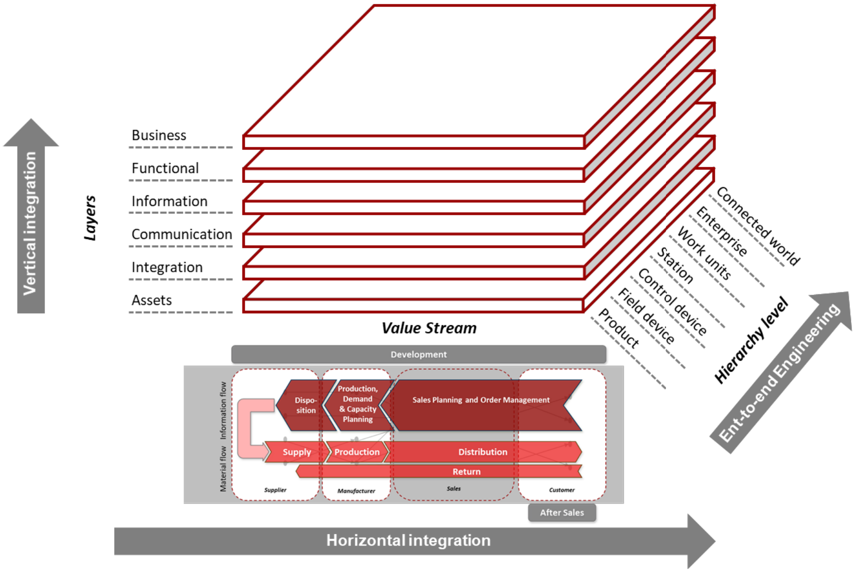



**Figure 16:** Reference frame for impact of digital transformation technologies[113,114]

The value stream shown represents a typical manufacturer's value creation. As described in section 4.3, this value chain will probably evolve towards a platform-based model of L&SCM. as shown in Figure 17. The value chain as displayed in Figure 15 is the basis for proceeding further, because as of today L&SCM is still structured in this way. However, it is foreseeable that manufacturing companies

[113] Cf. Adolphs et al. 2015, p. 7
[114] Based on Strandhagen et al. 2017, p. 345

will move forward toward value creation networks based on platforms. The exemplary platform provider represents all platform solutions for L&SCM, including freight platforms, platforms for streaming CAD/CAX data, data analytics platforms, applications for customer interaction, and others.

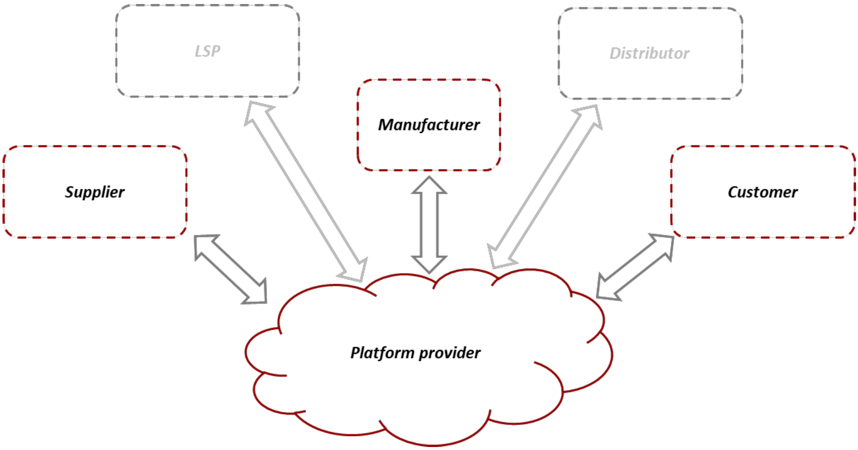



**Figure 17:** Future logistics and supply chain management value network[115]

## 4.5 Summary

The impact of DT on L&SCM of manufacturing companies is still unclear. An important factor is the willingness and ability of management to drive DT. Therefore, companies need to rethink activities from product development to delivery and after sales in order to focus on measures that are perceived as value enhancing for their customers. A company that has such a culture will be able to rapidly exploit the advantages provided by technological trends.[116] Barriers such as inconsistent data, missing standards, and lack of collaboration need to be overcome in order to move towards more autonomous processes in L&SCM. The reference frame presented in this chapter can help to create ontologies and a common un-

[115] Cf. Anderl et al. 2016, p. 12
[116] Cf. Morita et al. 2016

derstanding for L&SCM partners. This helps when designing technological solutions that affect more than one L&SCM partner and thus facilitates integration. The reference frame does not offer guidance for data sovereignty or data security. For this purpose, the Industrial Data Space proposes the IDS reference architecture model.[117]

Technologies can help to overcome the challenges mentioned above and can especially support fostering more customer-centric value creation networks. The following chapter describes and presents the DT technologies that are the focus of this thesis and their respective capabilities.

[117] Cf. Otto et al. 2018

# 5 Digital transformation technologies

Very often, the term DT technologies is used as a buzzword without indicating what exactly DT technologies are and what technologies are not "digital". However, authors agree that DT technologies have become important building blocks of value creation in manufacturing companies.[118] Technology itself has no real value to a company if it is not commercialized in a profitable manner. The basic components to foster DT in L&SCM are technologies to identify, locate, sense, process, and act.[119]

To grasp the difference between DT technologies and earlier technologies and to understand the logic of digital innovation, DT technologies have three unique characteristics: (1) re-programmability, (2) homogenization of data, and (3) the self-referential nature of digital technology.[120] Prices for sensors and actuators, which are enabling technologies, have declined significantly. This development enables new possibilities for applying enabling technologies, which are a prerequisite for providing more flexibility. Sensors used for identification, condition monitoring, and tracking and tracing can be applied in two different ways: either for the design of intelligent infrastructure with local equipment of the respective technologies or for the definition of mobile intelligent objects by equipping goods and operating material with sensors. The goal is a secure L&SCM network and full transparency of L&SCM processes at any time.[121] Relevant technology bundles (application technologies) in a DT context are new information technologies, including analytics, cloud computing, radio frequency identification, and additive manufacturing. Additional ones are robotics, digital networks (including internal and external digital platforms), artificial intelligence, and virtual reality (VR) or

[118] Cf. Schuh et al. 2016, p. 39
[119] Cf. Uckelmann 2008, p. 276
[120] Cf. Yoo et al. 2010, p. 726
[121] Cf. Schenk 2015, p. 247

AR.[122] To capture the benefits of DT potential, the steps of data capture and communication, data storage and analysis, and finally obtaining value from data are essential. Logistics experts agree that DT requires aligned and scalable logistics structures. DT technologies can help to foster adaptable and aligned SC networks and to create competitive advantage.[123] However, there is no scientifically based analysis available that relates DT technologies to L&SCM. To address this shortcoming and to build a basis for the continuation of this thesis, the next section describes a systematic literature review for structuring the topic of DT technologies with regard to logistics and SCM.

## 5.1 Systematic literature review

The literature review is based on a search string (see boxed text) in two databases: Business Source Complete and Web of Science. Despite the care taken in the SLR, the language (English), the selected keywords, and selected databases represent natural limitations.[124]

***(digital* OR Industry 4.0 OR smart) AND (logistic* OR SCM OR Supply Chain Management OR Supply Chain* OR SC) AND technolog* AND***

The literature search was conducted in May 2018. The initial search yielded 210 results for Business Source Complete and 178 for Web of Science. The search was not limited with respect to publication dates and includes all academic articles for which full text was available. The procedure for structuring the findings followed Mayring's qualitative content analysis approach. In the analysis below, the formal characteristics of the literature sample are presented and discussed before presenting the key findings. To progress the compilation of the DT technologies

[122] Cf. Morita et al. 2016
[123] Cf. Kersten et al. 2017b, p. 38
[124] The SLR has been used as a database for the publication: Junge 2020

and their capabilities and further key findings of the SLR, a summarizing qualitative content analysis is applied.[125] The findings described below build the basis for the subsequent analysis of the customer value originating from the implementation and use of these technologies.

**Criteria for title and abstract screening**

Papers needed to meet the following criteria to be considered for the literature review:

- They have to be relevant for manufacturing industry, as described in Chapter 4. This excludes publications covering process industries such as oil, gas, and electricity.
- They need to focus on L&SCM.
- They need to discuss the implementation or use of a concept or technology in the context of L&SCM and/or describe a classification/meta-analysis of Industry 4.0/logistics 4.0/DT in L&SCM with relevance for the research questions of this thesis.
- Papers focusing solely on optimization problems without discussing the associated technologies for the problem described were not retained (e.g., PPS).

After applying this set of rules, 101 relevant articles are kept for further analysis (47 results for Business Source Complete and 54 results for Web of Science). After removing duplicates and analyzing the content according to the criteria above, a list of 62 papers remained for further analysis.

[125] Cf. Mayring 1991, pp. 210 ff.

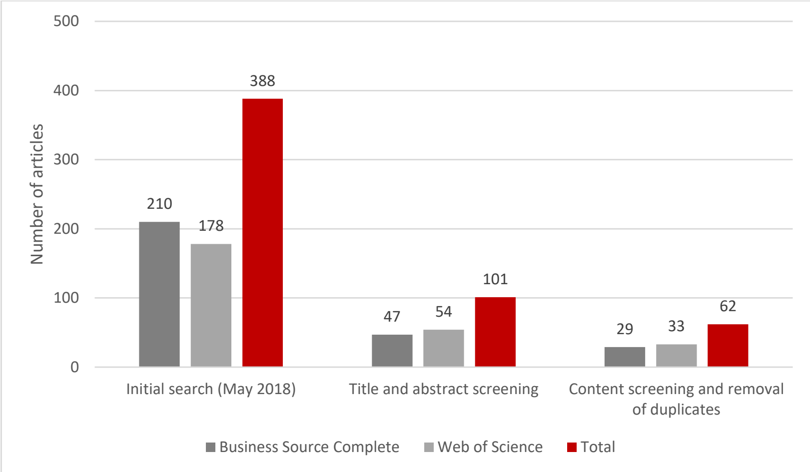



**Figure 18:** Results of systematic literature review[126]

The remaining papers were analyzed according to different dimensions, namely: the sample characteristics and the applied methodology; relation to STS theory as introduced in Chapter 2; whether the orientation is towards products and/or processes; the technologies discussed and employed; and the key findings.

**Sample and applied methodology**

Publications seem to reach a peak in 2017 following a continuous increase in numbers. It is to be expected that the number of publications in this area generally, and especially in L&SCM-related journals, will increase further in the future.

[126] This figure has been previously published in Junge 2020, p. 715

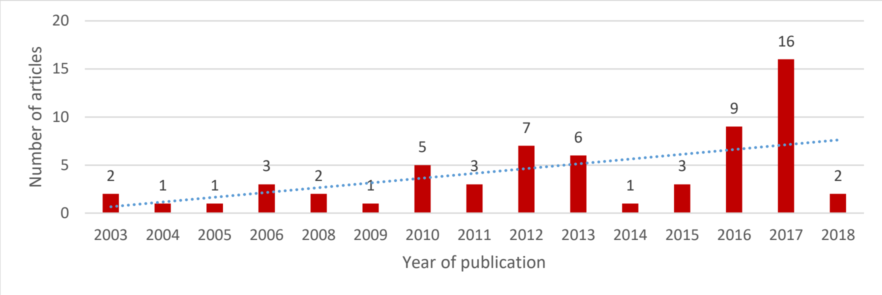



**Figure 19:** Literature body's year of publication

The sample of the 62 articles does not show a clear focus on one or several journals for publication. This underlines the interdisciplinarity of the topic. It is, however, remarkable that more of the retrieved articles are published in journals focusing on manufacturing, rather than L&SCM journals. The main sources of publication by number of articles found were:

- International Journal of Computer Integrated Manufacturing (n = 4)
- International Journal of Production Research (n = 4)
- Journal of Industrial Ecology (n = 3)
- Procedia CIRP (n = 3)
- The International Journal of Advanced Manufacturing Technology (n = 3)
- Advances in Manufacturing (n = 2)
- IFAC-PapersOnLine (n = 2)
- Journal of Systems Science and Systems Engineering (n = 2)
- Robotics and Computer-Integrated Manufacturing (n = 2)
- Journal of Business Logistics (n = 2)

Among the other journals were also L&SCM related ones, such as *Supply Chain Management: An International Journal*, but those focusing on IT or manufacturing are clearly more numerous. The methodologies applied in the articles mainly follow an exploratory research approach, as also chosen for this thesis. The main methodologies applied are case studies, surveys, simulations, and literature reviews. Exploratory research clearly dominates this research domain. The following sections present the key findings.

**Technological aspects**

DT gives a push to technology bundles that have been researched for quite a while. ICT and ID-technologies are the main foundations for L&SCM capabilities in the era of DT. Emerging technology concepts, such as VR/AR, CPS and distributed ledger, will grow in importance and such technologies must be studied in the real world. The main potential benefits that are associated with the implementation and use of DT technologies are facilitated collaboration, an increase in efficiency and agility, as well as improved quality and reduced costs.[127,128,129,130] However, there are several barriers hampering the use of the discussed technology bundles in capturing value. First, DT technologies alone do not create value. In particular, the implementation of ICT as the backbone of DT requires managerial skills, adaptation, and adequate back-end integration of internal business processes. Those factors become even more important in competitive environments.[131] ICT-enabled L&SCM integration capabilities, however, result in significant and sustained performance gains, for example, those relating to operational excellence and revenue growth.[132] Concerning the end-to-end integration of ICT systems, changes in power relationships, inadequate integration of internal business processes and information, limited flexibility of internal business processes, lack of IT sophistication amongst the smaller partners, and inadequate decision capability of ICT systems are some of the factors that limit their potential.[133,134] Long-term impacts on

[127] Cf. Grüninger et al. 2010, p. 2653
[128] Cf. Wang et al. 2010, p. 2513
[129] Cf. Zhou et al. 2011, p. 493
[130] Cf. Ackermann et al. 2013, p. 4628
[131] Cf. Dong et al. 2009, p. 31
[132] Cf. Rai et al. 2006, p. 225
[133] Cf. Seethamraju 2008, p. 1
[134] Cf. Holmqvist and Stefansson 2006, p. 269

enterprise systems and architectural landscapes are to be expected. This is why, with regard to the expected architectural changes to integration and decentralization, new architecture reference models are needed as guidelines.[135] A starting point for this can be the reference model based on the RAMI 4.0, as presented in section 4.4.

**Organizational, managerial and social aspects**

In general, the adoption rate of DT technologies is higher in large manufacturing firms.[136] When comparing the organizational, economical, ecological, and social focus of the papers at hand, social aspects are clearly understudied. Although the search string focused on technologies, it is surprising to see that only very few papers focus on the social aspects of technology adoption and use. This is especially important when referring to STS, the paradigms of DT and the fact that many DT endeavors fail owing to human factors. The topics discussed in the papers that refer to social aspects are managerial skills, training for skills management of employees, the relationship to the customer, and ergonomic aspects. Change management and future human–machine interaction are discussed to a lesser extent. Scholars agree that new types of expertise are needed to support the DT in L&SCM in manufacturing.

**Environmental aspects**

Environmental aspects are mainly addressed in papers discussing additive manufacturing. As products or parts might evolve to downloadable commodities, their distribution distances can be reduced.[137,138,139]

135 Cf. Prause and Weigand 2016, pp. 108f.
136 Cf. Marjanovic et al. 2017, pp. 31ff.
137 Cf. Hormozi 2013, p. 46
138 Cf. Baumers et al. 2017, p. SII
139 Cf. Tien 2012, p. 282

ICT can help to foster a circular economy for L&SCM, for example, through smart boxes owned by logistics service providers being responsible for their management (maintenance, status monitoring, information management, and recycling).[140]

**Network and structural aspects**

Only two papers explicitly discuss possible benefits for logistics service providers. Digital manufacturing, as a general-purpose technology, gives logistics service providers an opportunity to consolidate demand from initial users and incrementally to deploy capacity closer to new users.[141] This has to do with how the SLR was structured (focusing on manufacturing), but most research papers claim to follow an inter-company approach, so the small number is noteworthy.

Concerning increased or reduced complexity in L&SCM networks, contradictory voices arise. On the one hand, authors discuss the reduction of SC stages; on the other hand, new intermediaries enter areas that have previously been organized by traditional SC actors. For structural aspects the preparation for scaling is important, which means laying the technological basis at an early stage.[142]

**Orientation toward products and/or services**

This distinction will be relevant when discussing possible technology-enabled means for customer orientation. On the one hand, individualized products can create more customer centricity, while on the other hand, adapted services will also pursue this purpose as well. For further reference concerning hybrid service bundles combining products and services, including related business models in manufacturing, please refer to Mittag (2019).[143] The customer service process comprises activities associated with creating and delivering products and services to

[140] Cf. Zhang et al. 2016, pp. 6696 ff.
[141] Cf. Holmström and Partanen 2014, p. 421
[142] Cf. Dighero et al. 2005, pp. 254 ff.
[143] Cf. Mittag 2019

customers. Customer orientation and customer response capabilities are antecedents to customer service performance. These two capabilities help a company to sense and respond to customer needs locally in cases in which DT technologies provide high information quality. Testing of capability-building dynamics suggests that the impacts of information quality are contingent on local process characteristics, which is especially important when information availability will be more dispersed.[144] Chapter 6 will discuss the dimensions of customer value created by, for example, combining products and services in hybrid service bundles in.

One important aspect of the DT-driven integration and the widespread emergence of digital control systems in contemporary complex products is that original equipment manufacturers need to maintain competencies beyond the products that they manufacture.[145] They need to define competencies and control points that need to be controlled and kept in-house. Volkswagen announced in June 2019 that it would increase its own share of automotive software development from less than 10 percent to at least 60 percent by 2025.[146]

As a basis for further investigation, this thesis analyzes the technologies discussed in the 62 papers and maps them to their specific capabilities. Based on the literature analysis, the next sections present and describe the relevant DT technologies for L&SCM and then define and discuss their respective capabilities.

## 5.2 Capabilities of digital transformation technologies

This section is based on a quantitative text analysis. Based on the literature corpus derived from the SLR, the following analysis was conducted: The technologies mentioned in the papers were mapped to the capabilities they are associated with. The capabilities are derived from the ones that are associated with Industry 4.0

[144] Cf. Setia et al. 2013, pp. 565 ff.
[145] Cf. Lee and Berente 2012, p. 1441
[146] Cf. Volkswagen AG 2019

capabilities,[147] but are adapted to L&SCM characteristics. The "learning" capability enabled by analytics, which is a prerequisite for archiving L&SCM 4.0, is inherent in autonomy. Furthermore, the capability of decentralization is important as it relates to networks, and this is therefore added. The six capabilities of DT technologies as a basis for this thesis are:

- integration
- visibility
- real-time
- decentralization
- automation
- autonomy.[148]

These relate to the stages of data capture, communication and extracting value from data. Integration of systems is necessary to obtain a holistic picture of processes. Sensors and visualization tools allow for information visibility (for example, material flow). If available and processable in real-time, this information can be used for forecasting, communication among entities, and other analysis. This is needed to allow for extracting value from the data, which is apparent in either automated or autonomous execution or decision support in L&SCM networks. As the meanings of the six capabilities are not self-explanatory, they are put into context below.

Today's top companies use technology driven **integration** to improve L&SCM processes.[149] Integration means integrating isolated deployments of ICT to enable core business processes to mirror and connect to one another. As shown in Chapter 4, full integration of ICT and operational technology has not yet occurred.[150]

[147] Cf. Schuh et al. 2017, pp. 15 ff.
[148] Cf. Roy 2017, p. 77
[149] Cf. Ross 2011, pp. 39 ff.
[150] Cf. Schuh et al. 2017, p. 16

Integration is sometimes (erroneously) called interfacing or connectivity. Connectivity implies connecting processes together and interfacing the transmission of information from one system to another (electronic data interchange). They are both constituents of integration, but do not have the capability to integrate people and processes. The goal of integration is to align the challenges and opportunities offered by ICT and the culture and capabilities of the modern organization.[151] Exemplary technologies for integration can be categorized into unlicensed (e.g., Bluetooth), low-power wide-area (e.g., SigFox), cellular (e.g., LTE), and extra-terrestrial (e.g., GPS) networks. ICT, used for connectivity and interfacing, also includes relevant technologies. Companies should focus on use cases rather than sophistication when choosing integration solutions. Functionality and suitable standards for extension should be the guiding principles.[152]

**Visibility** means assured transparency about relevant information in L&SCM networks. Information systems communicate across those networks and manufacturers, suppliers, customers, and strategic partners share information. Platforms serve as information hubs.[153] This enabled visibility is also referred to as creating a network's digital shadow. One important problem is that data often does not have one single source of truth, as it is held in decentralized silos. Moreover, data is only captured for certain processes and made available to a restricted number of stakeholders. System boundaries hinder a comprehensive use of available data. Comprehensive data capture and provisioning is necessary to create overall visibility about operations and processes throughout L&SCM networks.[154]

Integration and visibility unfold their potential if information is available and processed in **real-time**. According to the technology standard ISO/IEC 2382-1 data

[151] Cf. Ross 2011, pp. 40 f.
[152] Cf. Alsen et al. 2017
[153] Cf. Kersten et al. 2017b
[154] Cf. Schuh et al. 2017, p. 17

are "a reinterpretable representation of information in a formalized manner, suitable for communication, interpretation or processing." There is a widespread assumption that capturing and sharing real-time information is key to improved L&SCM performance.[155] The capability of real-time can be described as being able to obtain the required information at the required time from the required object, system or people. This enables new forms of tracking and tracing, and an efficient responsiveness to changing conditions. A popular, advanced and widespread technology for this issue is radio-frequency identification (RFID). RFID is used for identification and thus belongs to auto-identification technologies.[156] It makes it possible to track items and to obtain information such as their identity, location, movement, and state. This helps to manage L&SCM networks more accurately.[157] Real-time capability means availability, processing and provision of data in up to several minutes. The exact time depends on the cloud's latency and it usually takes seconds or even less than a second. This time is also determined by hard and soft real-time requirements. Hard real-time requirements need to be assured in order to fulfil a function (e.g., airbag activation within hundredths of a second), whereas soft real-time requirements serve as comfort enhancement (e.g., a central locking system).[158]

**Decentralization** in this thesis takes on two meanings. First, it stands for decentralized information availability. CPS enables decentralizing intelligence and allows for, for example, decentralized production planning processes.[159] Decision power is shifted towards smart entities that can make decisions and execute tasks without any superior control. This new decentralized intelligence enables new planning processes. Integration of ICT and information systems and real-time data

[155] Cf. Cachon and Fisher 2000, p. 1032
[156] Cf. Xiao et al. 2007, p. 457
[157] Cf. Arica and Powell 2014, pp. 163 f.
[158] Cf. Scholz op. 2005, p. VI
[159] Cf. Bochmann et al. 2015, pp. 183 ff.

availability are perquisites. In addition, decentralization in this context is not unambiguous. On the one hand, intelligence is transferred to many entities but, on the other hand, comprehensive integration as depicted above requires one single source of truth and thus a centralized data reservoir. However, the understanding in this thesis concerning information and intelligence is that smart objects decentralize their disposability. The second meaning of decentralization is the physical decentralization of production processes, for example, as enabled by additive manufacturing[160] or promoted by the development towards micro factories.

> *The term **automation** includes the assumption of process control and, if necessary, process control tasks by artificial systems. Automation is the result of automatization, [...] (DIN IEC 60050-351). Automatic machines are artificial systems that automatically follow a program and make decisions based on the program for controlling and, if necessary, regulating processes [...]. The decisions of the system are based on the linking of inputs with the respective states of a system and result in tasks (DIN IEC 60050-351). Automatically running processes are often carried out according to the control loop principle – i.e. under target-oriented process influence through the feedback of control results.*[161]

**Autonomous systems**, in contrast to automated systems, comprises systems (e.g., machines) that are able to execute tasks without being explicitly programmed for those tasks and thus are able to learn. They go beyond automation technology by having autonomous cognition. This autonomous cognition involves sensing, awareness, deciding, acting, adapting, and learning. Autonomous systems are based on different architectures with different levels of complexity. They range from reactive to deliberative to cognitive architectures. Cognitive architectures, in contrast to deliberative architectures (sense-decide-act), add the capabilities of

[160] Cf. Durach et al. 2017, p. 967
[161] Cf. Voigt 2018a

situation awareness, adaption, and learning.[162] Cognitive autonomous systems use sensors for perception and apply automated reasoning and planning. Finally, actuators are used to execute the specific tasks. In order to optimize the functioning of autonomous systems, their perception and reasoning must be based on information representing the relevant environment in the best way possible based on emerging understanding from different internal and external sources.

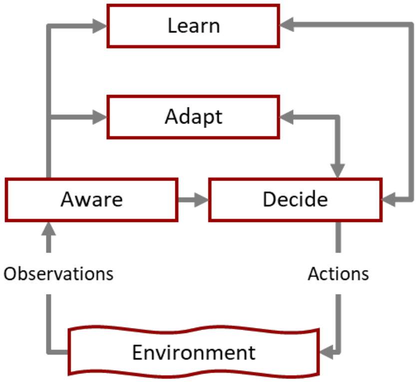



**Figure 20:** Cognitive system loop[163]

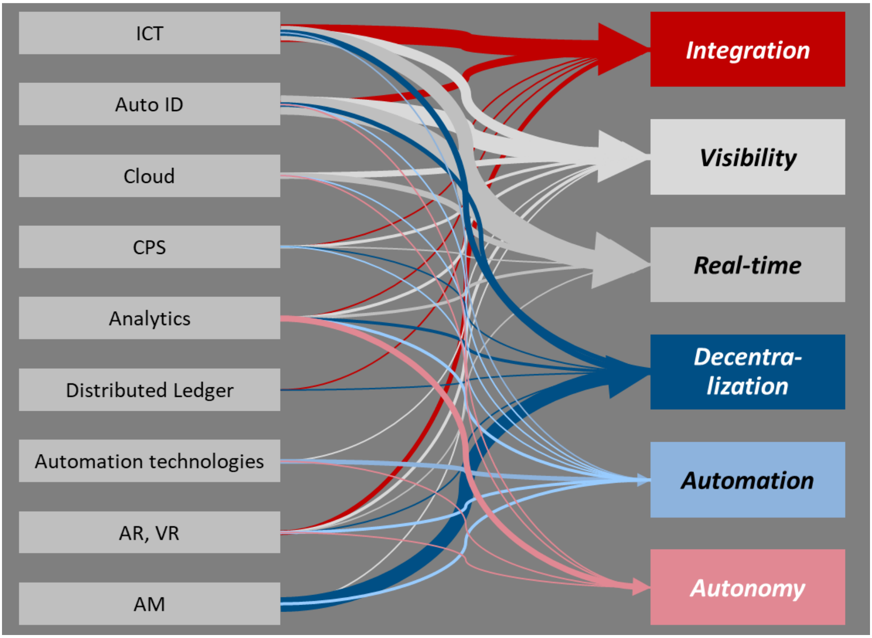
The right approach for DT integrates DT technologies with revamped operations. Assessments need to consider whether the two are sufficiently integrated. The supportive ecosystem needs to ensure that the company has a talent strategy and organizational structure in place favoring (open) innovation, entrepreneurial spirit, and continuous improvement.[164]

[162] Cf. Bayat et al. 2016, p. 474
[163] Bayat et al. 2016, p. 474
[164] Cf. Gezgin et al. 2017

**Table 7:** Definition of digital transformation technologies' capabilities

| Capability | Definition |
|---|---|
| **Visibility** | ▪ Assured transparency about relevant information for relevant stakeholders in L&SCM networks<br>▪ Traceability of products, machinery and processes |
| **Integration** | ▪ Alignment of challenges and opportunities offered by ICT and the culture and capabilities of an organization<br>▪ Data provisioning in a computer interpretable format, data consistency |
| **Real-time** | ▪ Ability to obtain the required data or information at the required time from the required object, system or people |
| **Decentralization** | ▪ (a) Decentralized information and intelligence<br>▪ (b) Decentralized production |
| **Automatization** | ▪ Assumption of process control and process control tasks by artificial systems |
| **Autonomy** | ▪ Systems with the ability to execute tasks without being explicitly programmed for those tasks and that thus are able to learn |

The Sankey diagram (Figure 21) shows the relation of the DT technologies with the previously described capabilities to depict the strongest associations. The diagram is based on the papers reviewed in the systematic literature analysis. For each paper, the discussed technologies are mapped to the stated capabilities. Each paper discusses at least one technology (the inclusion criterion for the SLR) and a technology can be related to one or several capabilities as described in the paper. The cumulative relationships are represented by the width of the arrows.




| | |
|---|---|
| ICT | Information and communication technology |
| ID | Identification |
| CPS | Cyber Physical System |
| AR/VR | Augmented Reality/Virtual Reality |
| AM | Additive Manufacturing |

**Figure 21:** Digital transformation technologies' capabilities[165]

It is obvious that scientific research papers published before May 2018 show a clear focus on ICT and auto identification technologies to enable the integration, visibility, and real-time capabilities of networks. This is also confirmed by the findings of the research study "Pathway of Digital Transformation in Logistics."[166]

[165] For a representation by numbers, please refer to the table in Appendix A.
[166] Cf. Junge et al. 2019, p. 46

## 5.3 Summary

The analysis and evaluation of research as well as practice has shown that the basis for partly or completely automated autonomous processes is currently being built. Once the challenges described in section 4.2 are overcome, the building blocks of data capture and communication will be in place. This leads to the third development stage: extracting value from the data, which relates to the capabilities of decentralization, automation, and autonomy.

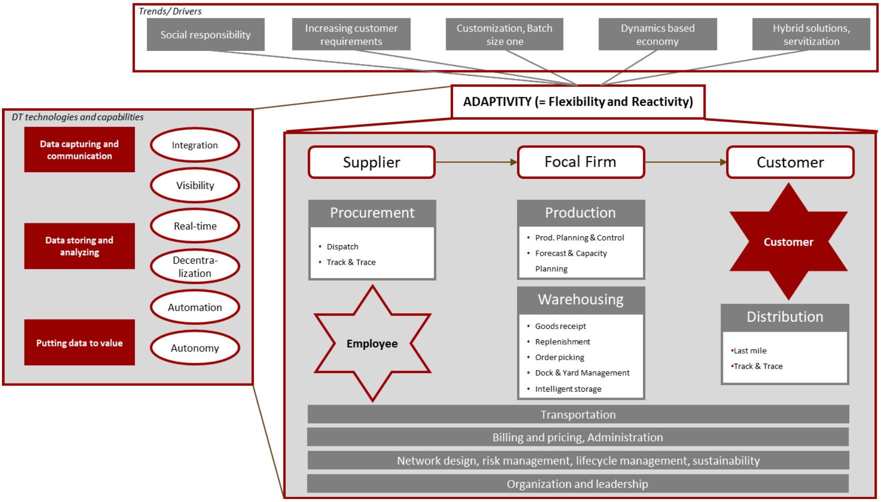



**Figure 22:** Framework of digital transformation in logistics and supply chain management

As discussed above, the objectives that DT in L&SCM pursues are increased adaptivity, efficiency, and customer centricity leading to enhanced customer value. As customers are the ultimate driver of DT activities, chapter 6 will describe the relevance of DT technologies for customer value and how this is linked to L&SCM performance differentiation.

# 6 Conceptualizing customer value in logistics and supply chain management

Customer desires are becoming more individual. The desire for differentiation is increasingly expressed in the personalization of products, services, and experiences. Customers use digital configurators to individualize and design items, or they are individualized for them by giving companies insights into their preferences via social media. Creating and owning highly individualized products and experiences becomes a new status symbol and gives consumers the feeling of living uniquely.

Alongside individualization, customer or user experience is becoming increasingly important. In a recent survey of more than 6,700 end customers and shoppers by Salesforce, approximately 80 % of respondents said that the customer experience is as important to them as the products and services themselves and that they expect companies to understand their needs and expectations.[167] In the business-to-business (B2B) area, an increasing number of customers expect an Amazon-like personalized shopping experience. For Germany, 87 % of customers state that treating them as a person instead of a number is very important for winning their business. B2B customers use eleven channels on average to communicate with companies; for business-to-consumer (B2C) models, it is ten channels, of which the preferred ones are online portals, mobile apps, text (e.g., email and short message service (SMS)), and online communities. The preferred channels vary greatly between countries, with the preferred one in the USA being text communication, such as emails and SMS.[168] However, this highlights only customer interaction. Concerning supply and production, global enterprises are aiming to bring facilities closer to the customer. This includes switching from the low-cost production capabilities of outsourcing and offshoring back to more individual strategies, such

[167] Cf. Salesforce 2018, pp. 6 ff.
[168] Cf. Salesforce 2018, pp. 24 ff.

as intelligent sourcing and X-shoring, as in the example of Local Motors in Chapter 4. This affects network organization and SCM as companies have to find more raw materials from different sources and finished product distribution occurs via diverse channels and delivery means.[169]

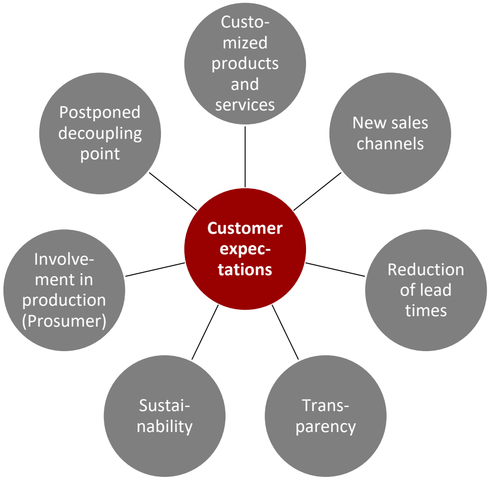



**Figure 23:** Customer expectations in a logistics and supply chain management context

Considering various customer expectations, this chapter aims to conceptualize the customer value added by DT in L&SCM: first, by giving an introduction to L&SCM performance differentiation; second, by stating the impact of DT(T) on L&SCM performance; and third, by summarizing the implications for creating competitive advantage. Based on this, definitions for customer centricity and customer value in the era of DT are proposed as well as a conceptualization for the latter. This serves as the input for an NGT workshop among 19 L&SCM experts, which mirrors and enriches the theoretical findings and proposed conceptualization.

[169] Cf. Bubner et al. 2014, p. 36

## 6.1 Definition approach customer value

In a narrow sense, customer value is the perception of benefits per total costs of ownership.[170]

$$Customer\ Value = \frac{Perception\ of\ Benefits}{Total\ Cost\ of\ Ownership} = \frac{Quality\ x\ Service}{Cost\ x\ Time}$$

Quality means the reliability of the features, functions, and performance of the offer. Service includes availability, support, service, and commitment provided by the offer during the pre-transaction, transaction, and post-transaction periods. The buyer's transaction costs include price and life-cycle costs. Time can be understood as the time taken to respond to customer requirements.[2] This view of customer value is a condensed one but includes some of the major constituents for creating perceived customer value and thus customer loyalty. CRM is the discipline concerned with this task. CRM is a strategic tool that includes marketing, sales, services, and supporting technologies to foster customer relationships in order to increase value, revenue, efficiency, and unique solutions to business problems.

CRM focuses on the following:

- **Facilitation of the customer service process**: Higher responsiveness relies on the sales and service functions' capability for identifying what brings real value to the customer. This assumes the availability of data, metrics, and analytics to provide a comprehensive, cohesive, and centralized portrait of the customer (segment of one).
- **Optimization of the customer's experience**: CRM's goal of owning the customer experience means personalized service, customized products as well as

[170] Cf. Wallace and Xia 2015, pp. 35 f.
[171] Cf. Wallace and Xia 2015, pp. 35 f.

using advertising, ease of product ordering, or a service that has a positive impact on the customer's buying experience. The aim is to personally connect the customer to the supplier and to show him the supplier's ability to deliver.

- **Provision of a window to the customer**: All control points (service nodes) along the L&SCM network influencing the customer experience should be provided with the customer’s critical information. These can be the constituents they value most and the key elements for enabling a positive buying experience at any time. Data to enable insightful analytics have to be all-pervasive and integrated (e.g., buying habits, pricing and promotions, channel preferences, and historical contact information).
- **Assistance for suppliers to measure customer profitability**: Companies need to know which customer segments or even individual customers are profitable and which are not; what products or services drive profitability; and how actors along the value chain can build processes that deliver the utmost customer value.
- **Facilitation of SC collaboration**: Customer interactions are one instance in a long chain of events progressing from one SC entity to the next. Companies need to design integrated and synchronized processes in order to satisfy the customer seamlessly across the L&SCM network and hence create sustainable competitive advantage.[172]

The research stream concerning customer value in L&SCM is mainly driven by researchers from the United States. In 1992, Langley and Holcomb stated that the coordinative and integrative character of L&SCM provides various dimensions to create further customer value. Value can be created both internally and externally. Taking into account attributes such as customization, flexibility, innovation, and responsiveness results in service levels that become the standard for competitive advantage.[173] For creating sustainable competitive advantage, an increasingly important requirement is to identify the demands and values of current and future

[172] Cf. Ross 2011, pp. 162f.
[173] Cf. Langley and Holcomb 1992, pp. 8 ff.

customers.[174] Customer value is based on the perspective; a customer-based definition of customer value integrates understanding of the customer's perceived value.[175]

In the era of DT customer centricity assumes a new meaning: *"For me, customer centricity is a digital interface to the customer covering the entire experience – from the first inspiration to purchase to delivery and completion. Only those companies that truly put the customer at the heart of their operations will succeed in the future*" (Dr. Christian Langer, Vice President Digital Strategy, Lufthansa Group).[176]

The end customer is regarded as the main driver of DT.[177] Thus, the technological potential regarding transparency, real-time capability, and configurability of processes and products must be consistently tested for meeting customer needs and adding customer value. A faster response to customer needs and higher customer satisfaction are two of the three most important attributes that experts expect from the use of such technologies.[178] Aspects to be considered include mobile data access for customers, customizable products, new ways of addressing customers, and the offering of hybrid service bundles. All these offerings are aimed at further increasing corporate performance against the background of classic goals such as improving product and process quality, flexibility, and reliability, and reducing cost.

The positive effect of customer orientation on the performance of companies (e.g., success in launching new products, sales growth, and return on investment) is documented in the scientific literature.[179,180] An essential factor, which was high-

[174] Cf. Mentzer et al. 1997 p. 630
[175] Cf. Mentzer et al. 1997, p. 633
[176] Cf. Chung et al. 2018, p. 7
[177] Cf. Kersten et al. 2017b, p. 12
[178] Cf. Morita et al. 2016
[179] Cf. Appiah-Adu and Singh 1998, p. 385
[180] Cf. Sik Jeong and Hong 2007, p. 578

lighted as early the end of the 1980s, is the generation of product-based services.[181] However, as the level of digitally consumed content increases, this factor takes on a new meaning. Customers are used to being able to access information anywhere and at any time. This is also reflected in the way information, especially news, is received. While consumption in digital form has been at a very high, but stable, level for some years now, consumption via social media platforms is gaining in importance within digital media.[182]

For manufacturing companies, this means that completely new ways of addressing and analyzing customers are emerging. In order to anchor the exploitation of these possibilities in the strategy of a producing company, it is first necessary that employees across all functions are aware of the importance of understanding customer wishes. Furthermore, they must orient their daily activities toward fulfilling these customer wishes, thus generating a high level of customer loyalty. Employees who are in direct contact with customers play an important role in achieving this.[183]

### 6.1.1 Logistics and supply chain management performance differentiation

L&SCM performance has several dimensions that can be categorized in terms of efficiency, effectiveness, and differentiation, where all the three dimensions are necessary to the accomplishment of L&SCM activities. Although it has long be assumed that the dimensions are mutually exclusive, research now suggests that the performance dimensions reinforce each other. Furthermore, excellence in logistics performance is related to higher organizational performance.[184] L&SCM's integrative and coordinative character provides various dimensions and ways to create customer value.[185] Management focus in L&SCM needs to include the

[181] Cf. Bowen et al. 1989
[182] Cf. Newman et al., pp. 10 f.
[183] Cf. Liao and Subramony 2008, p. 317
[184] Cf. Fugate et al. 2010, pp. 45 ff.
[185] Cf. Langley and Holcomb 1992, p. 8

whole value network. Historically, many companies treat their customers respectfully while putting a lot of pressure on their suppliers and vendors. This approach is counterproductive to a truly value-added perspective. Companies' target areas for creating added value through L&SCM should be setting clear objectives to achieve customer satisfaction, determining and assigning responsibility for systems and processes, and incorporating marketing basics into the processes of L&SCM.[186]

**Table 8:** Dimensions for logistics and supply chain management differentiation

| Source | Topic | Content |
|---|---|---|
| Hilletofth (2009) | Differentiated SC strategy | Differentiated SC strategy basically can be developed in the following four steps:<br>(1) developing a segmentation model;<br>(2) understanding the market we serve;<br>(3) understanding the capabilities to serve the market; and<br>(4) developing necessary SC solutions.[187] |
| Doch (2013) | SC performance differentiation | • Geographical performance differentiation<br>• Product oriented performance differentiation<br>• Product lifecycle-oriented performance differentiation<br>• Customer segment-oriented performance differentiation[188] |
| Hofmann and Knébel (2013) | L&SCM activities for performance differentiation | • Responsive and effective SC<br>• SC agility<br>• Customer decoupling point approaches<br>• Postponement strategies<br>• Mass customization<br>• Competitive SC priorities<br>• Market oriented SC differentiation<br>• Logistical service level differentiation<br>• Process of customer co-production<br>• Product-associated services[189] |

[186] Cf. Langley and Holcomb 1992, p. 9
[187] Cf. Hilletofth 2009, p. 28
[188] Cf. Doch 2015, pp. 114 ff.
[189] Cf. Hofmann and Knébel 2013, p. 21

The examples above illustrate possible avenues for L&SCM differentiation, but in order to be understood as differentiation, the factors need to be directly perceptible by customers[190].

Recent research papers have connected, L&SCM concepts to customer requirements. Hofmann and Knébel (2016) propose the SC Differentiation Trinity Model. This model consists of three dimensions. The first includes all L&SCM activities necessary to assure product allocation, which relates to delivery and distribution channels. The value of availability falls into this dimension. The second refers to differentiation options that consider relevant product service options, labeled "service supply chain." These relate to value of use. The third dimension is associated with the production process itself (make) and focuses on L&SCM activities that have a direct impact on product features and the product manufacturing process. This dimension is of value for the customer by virtue of co-production. The customer-relevant performance attributes are hence: product features, the manufacturing process, product allocation, product services, and effectiveness. Efficiency as well as a certain quality level of customer collaboration are considered as constraints.[191]

The following section links the three deduced value categories created by L&SCM differentiation, namely value of availability, value of servitization, and value of co-production or integration to the capabilities of DT technologies.

### 6.1.2 Impact of technologies' capabilities on performance differentiation

As the previous elaborations have shown, L&SCM is well positioned to add customer value[192] and Chapter 5 highlighted the capabilities that DT technologies enable. This raises the question of how the latter can contribute to the first and thus can help to create more responsive and value-adding L&SCM processes?

[190] Cf. Hofmann and Knébel 2016, p. 162
[191] Cf. Hofmann and Knébel 2016, pp. 162 ff.
[192] Cf. Langley and Holcomb 1992, p. 2

The evolution of the internet and new search engines and algorithms have changed customer buying habits, thus leading to the situation that customers are less inclined to stay faithful to past relationships and are often looking for suitable substitutes. This requires companies to design their L&SCM networks in a customer-centric way and to find the right mechanisms to build sustainable customer loyalty. Sensors, actuators, the use of mobile devices as well as tracking of online behavior, in combination with other data sources such as weather and traffic reports, call for integration with intelligent IT systems to leverage potential advantage by creating more adaptable networks. The resulting data availability constitutes one of the possible mechanisms for the convergence of marketing, sales, and service functions through designing real-time, synchronized L&SCM networks that add expanding value to the customer.[193]

Fleisch et al. identify three important characteristics that are essential for DT's business model patterns, all of which are related to customers:

- integration of users and customers: DT technologies enable integrating customers into the value-creation chain. This means that some tasks can be delegated to customers.
- service orientation: run-time and after-sales services related to the sold products are possible because these products are equipped with intelligence. This development is labelled as hybrid service bundling and allows companies to generate additional revenue and foster customer relationships.
- data analytics: the collection of customer data (transaction as well as use data) provides an asset than can be turned into value. Exemplary areas with relevance are product design, pricing, and sales structuring.[194]

---

[193] Cf. Ross 2011, p. 160
[194] Cf. Fleisch et al. 2014, pp. 3 f.

Hofman and Rüsch propose a logistics-oriented Industry 4.0 model,[195] which is based on Fleisch et al.[196]. They see three different value enhancers for the customer: value of data availability, value of digital integration, and value of digital servitization.

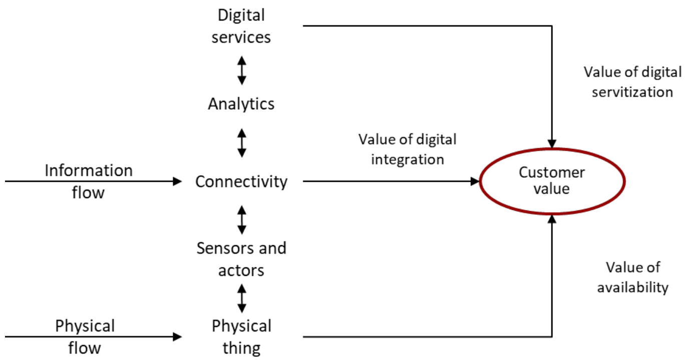



**Figure 24:** A logistics-oriented Industry 4.0 application model[197]

This thesis enlarges these authors' focus and provides insights into avenues for concrete customer value added. Specifically, the addition consists of the value proposition of cognition, which refers to autonomous capabilities enabled by DT technologies. This value proposition relates to extracting value from data. It frames the other three value propositions. Value of availability in combination with value of cognition leads to offers such as prescriptive demand forecasting combined with autonomous shipments. Servitization and cognition are already in use, for example, in the case of smart contracts based on distributed ledger technology. For the value of integration, customization assistants based on learning algorithms will provide a new customer experience. Hence, it is observable that the value of cognition represents a value enhancement to the other three value propositions.

[195] Cf. Hofmann and Rüsch 2017, p. 26
[196] Cf. Fleisch et al. 2014, p. 7
[197] Hofmann and Rüsch 2017, p. 26

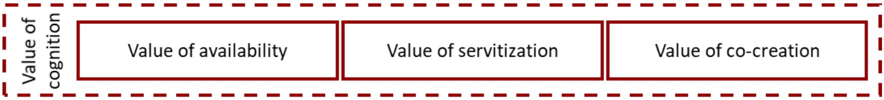



**Figure 25:** Digital transformation technologies' customer value[198]

### Value of availability

The value of availability as a topic of investigation of this thesis can be categorized according to physical or informational availability, and internal (focal firm) or external availability, which includes suppliers and customers. In the pursuit of DT, the informational availability assumes increasing importance, but one of L&SCM's main goals is still to have the right product at the right place in the right time and quality, so the physical dimension is not to be underestimated. The growing availability of data concerning products and processes reveals opportunities for proposing new services. This interpretation of value of availability goes beyond that proposed by Hofmann and Rüsch (2017) because it also includes the capabilities of visibility and real-time as described in Chapter 5 (e.g., a digital twin of production facilities). Hofmann and Rüsch generalize the value of availability to availability of products and services.[199]

### Value of servitization

The value of servitization is characterized by services based on DT technologies capabilities. Such services can be tracking and tracing systems, including risk mitigation options provided in real-time or after-sales services such as predictive maintenance. These services provide, on the one-hand, additional value for customers and, on the other hand, new revenue streams for the focal firm if commer-

[198] Cf. Hofmann and Rüsch 2017
[199] Cf. Hofmann and Rüsch 2017, p. 26

cialized in a profitable manner. They can also contribute significantly to improving customer loyalty if they are able to create an ecosystem that adds perceptible value for users.

**Value of co-creation**

Value of co-creation means the value provided by integration of and co-creation with customers and stakeholders. Customer-centric solutions based on DT technologies mean that customer and producer move closer together. Customers can design products according to their wishes through online configuration tools. In the product lifecycle, products equipped with intelligence can provide the producer with data that can be used to improve products and services. Such a development means that interaction-based monitoring of customers will provide a new window to them for producers.

Zaki et al. (2017) have captured this development of using data analytics to close the gap between manufacturers and consumers by proposing a conceptual framework. This framework is based on the assumption that consumers will be integrated in value creation. It consists of creating motivation, selecting the co-creation form,[200] determining engagement conditions that include the means of collaboration, providing digital operations to enable the co-creation, and finally measuring the resulting performance. The analysis of co-creation processes in the consumer goods industry revealed a model for how firms can shift towards more redistributive manufacturing with tasks delegated to customers. The first constituent is to test novel innovation processes by collaborating continuously with customers. Second, open innovation should be pursued to bring together stakeholders who are traditionally separated in the innovation process. Tools and methods for crowd engagement can incentivize customers. This can include tailored news, online idea contests or physical events. Multiple channels for communication with

[200] For more information on open innovation tools and methodologies for logistics service providers please refer to Reipert 2019.

customers should be tested, evaluated and maintained in order to be more responsive to demand through continuous dialogue. An enhanced user experience can positively influence a lasting customer relationship.[201]

**Value of cognition**

The value of cognition is, as already briefly described, an enhancement. Enabling cognitive abilities in L&SCM, although not yet implemented to a wide extent, distinguishes best practice companies from others.[202] Possible scenarios based on autonomous L&SCM are autonomous marketplaces and cognitive detection of demand that triggers autonomous production and shipment. Intelligent systems will assess myriad constraints and alternatives through simulations, thus providing decision support for executives. Decision support can evolve to autonomous decision making, for example, in the case of disruption when autonomous reconfiguration happens. The newly acquired intelligence in L&SCM networks will not only be used for real time decision-making, but for prediction purposes as well. With sophisticated modelling and simulation capabilities intelligent L&SCM processes will move past sense-and-respond towards predict-and-act.[203]

**In L&SCM, customer value based on digital transformation technologies can be described as value of availability, value of servitization, value of co-creation, and value of cognition as enhancement.**

These new value propositions of L&SCM call for new KPIs to measure the performance of L&SCM. The following paragraphs do not intend to give a comprehensive overview of performance measurement in L&SCM, but to introduce some new metrics that can be considered in the course of DT.

[201] Cf. Zaki et al. 2017
[202] Cf. Junge et al. 2019, p. 34
[203] Cf. IBM Institute for Business Value 2010, p. 33

### 6.1.3 Customer oriented key performance indicators

Leading companies focus on two DT activities. First, they reshape customer value propositions, and second, they transform their operations for greater customer interaction and collaboration. Activities previously labelled as marketing integrate into and influence upstream activities. Because customers are continuously connected, new interfaces and communication channels arise. Information about the products becomes equally important as the product itself, so companies must create and deliver content, which responds to the demands of social networking. This means that for businesses, including B2B, personal, timely and relevant information is key.[204] On the one hand, classical L&SCM KPIs can be enriched or simplified; on the other hand, customer-related ones could be introduced.

Research suggests the for L&SCM performance measurement "less is better" for KPIs. The focus should be on a small list of KPIs that are critical for sales and operations, customer service, and finance. KPIs can be categorized according to, for example, the SCOR model dimensions (plan, source, make, and deliver) and should be grouped into primary and secondary metrics.[205]

Table 9 displays exemplary typical KPIs.

**Table 9:** Exemplary logistics and supply chain management key performance indicators[206]

<table>
<tr><th colspan="3">Plan</th></tr>
<tr><td colspan="3">▪ Forecast accuracy<br>▪ Inventory turnover<br>▪ Days of inventory<br>▪ Planning cycle time<br>▪ Forecast vs. order</td></tr>
<tr><th>Source</th><th>Make</th><th>Deliver</th></tr>
<tr><td>▪ Vendor lead times<br>▪ Vendor fill rate<br>▪ Auto purchase-order rate<br>▪ Materials quality</td><td>▪ Weekly plan keeping<br>▪ Daily plan keeping<br>▪ Production lead time<br>▪ Production quality<br>▪ Job change overtime<br>▪ Capacity utilization</td><td>▪ On-time shipment<br>▪ On-time delivery<br>▪ Perfect order fulfilment<br>▪ In-stock availability</td></tr>
</table>

[204] Cf. Berman 2012, p. 17
[205] Cf. Chae 2009, p. 422
[206] Cf. Chae 2009, p. 424

DT technologies' capabilities enable, for example, advanced forecast accuracy and a better overall decision basis. However, customer-related KPIs that take into account new developments as described are currently missing in most organizations. Further KPIs worth considering are:[207]

*"Organization, sales and skills*

- *digital maturity quotient of the employees including board and senior leaders*
- *% revenue through digital channels*
- *contribution to digital initiatives from each organizational unit.*

*Customer Focus*

- *net promoter score*
- *rate of new customer acquisition*
- *number of customer touch points addressed to improve customer experience positively*
- *% increase in customer engagement in digital channels*
- *reduction in time to market new products to customers*
- *change in customer behavior over time across channels.*

*Return on innovation*

- *% of revenue from new products/services introduced*
- *% of the profit from new ideas implemented*
- *number of innovative ideas reach concept to implementation*
- *number of new products or services launched in the market*
- *number of new business models adopted for different class of customers*
- *rate of new apps and application programming interfaces to offer new products and services inside and outside the company."*

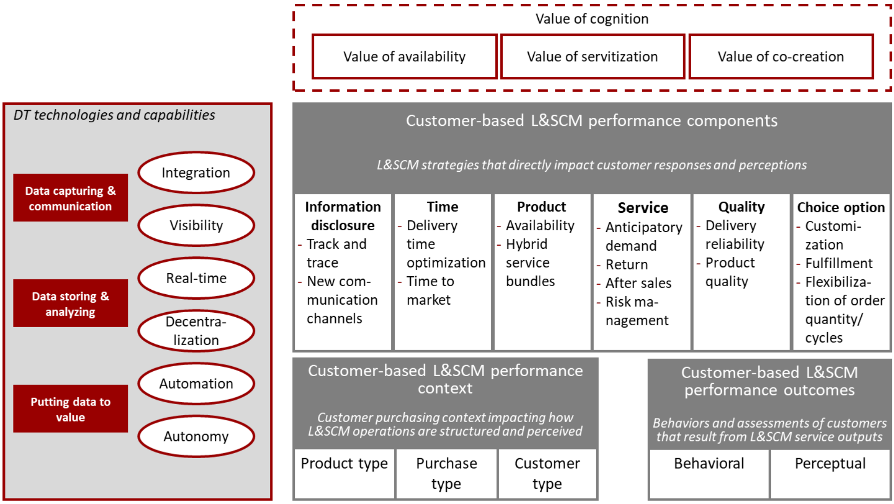
[207] Raut 2017

L&SCM KPIs for the DT era need to be able to depict the performance of projects with short cycles and to deliver insights about customer specifics. L&SCM experts agree that the Segment of One enables new sales opportunities for L&SCM and new customer value.[208] In the long term, companies should be able to measure how successfully a customer can navigate across an ecosystem and should be able to link this to L&SCM metrics (customer lifetime value).

### 6.1.4 Implications for creating a competitive advantage

Academia has begun to emphasize the measurement of L&SCM from the perspective of the customer. Concepts such as consumer-based L&SCM performance are defined as indicators of L&SCM processes and decision effectiveness and efficiency that rely on or are influenced by customer insights. Customer-based L&SCM performance can be structured into components, context and outcomes.[209] Based on the previous elaborations the following morphological box is proposed that conceptualizes customer-based L&SCM performance based on DT technologies.

[208] Cf. Junge et al. 2019, p. 14
[209] Cf. Esper et al. 2017, pp. 397 ff.




DT Digital transformation

L&SCM Logistics and supply chain management

**Figure 26:** Customer-based logistics and supply chain management performance[210,211]

As this thesis goes forward, it will focus on the performance components instead of context and outcomes.

The proposed components are information disclosure, time, product, service, quality, and choice options. These directly affect customer perceptions and are in line with the components of the business model evaluation of customer-centric SC as described by Melnyk and Stanton (2017).[212] They include the typical components such as time, product, quality, and services. The distinction between product and service-related features will become less distinct as products are equipped with intelligence and are sold as hybrid service bundles. Information disclosure and choice options are enabled by DT technologies' capabilities and can lead to new customer value added. This conceptualization provides a frame for customer

[210] Cf. Hofmann and Rüsch 2017, p. 26
[211] Cf. Esper et al. 2017, p. 404
[212] Cf. Melnyk and Stanton 2017, pp. 11 ff.

value propositions based on DT technologies. The components should be seen as indicative rather than as exhaustive. To capture the status quo of customer-based L&SCM performance components based on DT technologies in practice, the following section provides insights based on a workshop among L&SCM experts.

## 6.2 Status quo of customer-based performance components

The research aim of the NGT workshop as described in this section is to provide a conceptual description[213] for customer-based L&SCM performance based on DT technologies. It is structured as follows: first, the methodology and the results are described, followed by a discussion. The findings then feed into the framework presented in section 6.3.

### 6.2.1 Methodology

In October 2018, a NGT process was conducted. NGT is a structured methodology that aims at decision gathering among a panel of experts. The format is as follows: (1) First, individual members write down their ideas in silence and independently. (2) This step is followed by a round-robin procedure. One after another, each participant presents his or her ideas to the group without discussion. The ideas are summarized and written on a flipchart or another suitable analogue or digital medium. (3) After the individual idea presentation, a discussion takes place for clarification and evaluation. (4) The meeting concludes with a voting or ranking procedure adhering to the group's decision rules. The group decision is then pooled based on the individual votes.[214]

The method was slightly adapted due to the research setting. The NGT panel, as displayed in Table 10, was split into four groups, each of which had a moderator. The NGT was conducted in two phases. The first phase followed exactly the procedure as described above within the four groups. The outcome was the top strategies of the respective groups. In the next phase, this served as an input for an

[213] Cf. Meredith 1993, p. 8
[214] Cf. van de Ven, A. H. and Delbecq 1974, p. 606

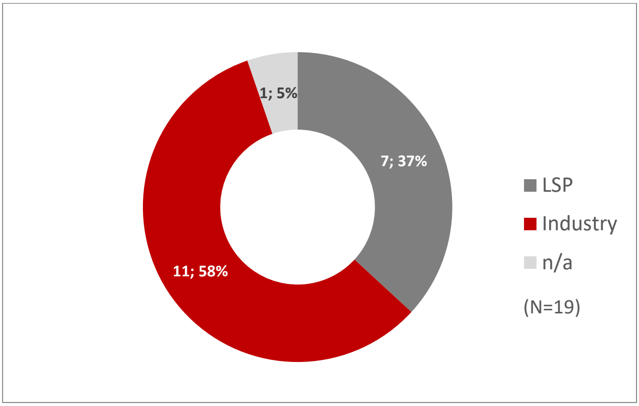
open panel where all of the participants presented and discussed the previously obtained results followed by a final voting to re-rank the strategies and come to a collective conclusion for the NGT. The results and concrete research questions that the participants were confronted with are described in the following.

The participants of the NGT workshop are experienced logistics managers based in Germany or Switzerland. Their companies operate mainly globally. Table 10 shows an excerpt of the database.

**Table 10:** Nominal group technique's database

| Industry | n | Revenue | n | Total number of employees | n |
|---|---|---|---|---|---|
| **Automotive & Vehicle Manufacturers** | 3 | 0.1-0.5 bn | 2 | 1,000-5,000 | 5 |
| **Electronics** | 1 | 0.5-1bn | 2 | 5,001-10,000 | 4 |
| **Machinery** | 7 | 1-5bn | 11 | 10,001-20,000 | 5 |
| **Consumer Goods** | 2 | 5-10 bn | 7 | 20,001-50,000 | 8 |
| **Retail** | 2 | Above 10 bn | 7 | Above 50,000 | 7 |
| **Construction** | 1 | | | | |
| **Agriculture** | 1 | | | | |
| **Logistics Service Provider** | 12 | | | | |
| | | | | | **N = 29** |

The sample as displayed in Table 10 consists of 29 participants. However, for the first phase, the idea generation, 19 evaluable sheets were generated, as Figure 27 shows. The complete panel participated in the discussion and voting procedure. The voting took place as follows: Each participant disposed of three voting points for the first and the second phase, which they could attribute freely. This meant that they could either give three points to one strategy or distribute them according to their preferences. They also did not need to assign all the points.




LSP Logistics Service Provider

**Figure 27:** Nominal group technique's panel evaluable responses (1st phase)

The participants were first given an introduction and a definition of DT in L&SCM as described in Chapter 3 in order to obtain a common understanding of the subject. The DT technologies found to be relevant for DT in L&SCM (refer to Chapter 5) were also given as input. Missing technologies could be added if the ones presented were deemed insufficient for the strategies that the participants had in mind. Subsequently they filled in the template for idea generation. The template, results of the idea generation and the two voting rounds are available in Appendix B.

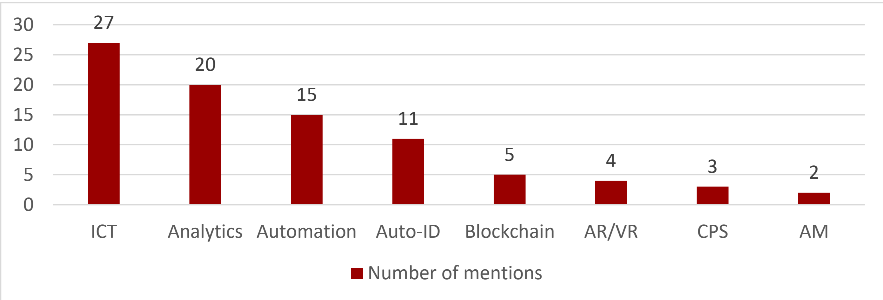
The underlying research question was: What are the Logistics and SCM strategies based on the presented technologies that increase customer value? In the idea generation phase participants additionally stated in what time horizon they expect the strategy to materialize and rated the importance for their companies' strategic goals. The next section describes the results, followed by a brief discussion.

### 6.2.2 Results

**Idea generation**

In the first phase, the idea generation, 57 strategies were recorded (based on n = 19 evaluable response sheets).

The technologies stated to be constituents of the pursued strategies are mainly ICT, analytics automation, and auto-ID. This is in line with the findings of Chapter 5, except that the importance of data analytics is higher in the perspective of the NGT panelists when compared to the foci of the literature body in Chapter 5.




| | |
|---|---|
| ICT | Information and communication technologies |
| ID | Identification |
| AR/VR | Augmented Reality/Virtual Reality |
| CPS | Cyber Physical Systems |

**Figure 28:** Technologies applied for strategies to increase customer value

The clustering of the strategies proposed after the workshop revealed eight thematic clusters. It is remarkable that the measures and strategies proposed are mainly focused intra-organizationally. The clusters are

- transparency based on data
- software integration
- transport, delivery and autonomous driving
- automated material flow and picking
- predictive maintenance

- decentral intelligence
- customer interface/connection
- cross-sectional topics (e.g., risk and compliance management).

After the idea generation, a first discussion within the groups took place to discuss the ideas and to come up with around ten ideas per group for voting.

**Table 11:** Nominal group technique's clustered strategies (Phase 1)

| L&SCM performance component | Strategies |
|---|---|
| Information disclosure | GPS tracking for live customer portal |
| | Smart container (live tracking for customers: GPS and temperature) |
| | Track and trace |
| | App for drivers (provision of real-time information) |
| | IT interface driver app and customer's IT system |
| | Drones for seed supervision |
| | Digital customer interface (app for customers) |
| | E2E communication and collaboration platform |
| | Transparency and data availability |
| | Reduction of media discontinuities |
| Time | Optimized and automated processes and flows (flow of goods, end-to-end) |
| | Fully automated warehouse (also quality related) |
| | Automatic clutch (rail) |
| | Autonomous train clutching and separation + autonomous train driving |
| | B2C e-commerce: expand order intake […] and prepare items in fully automated pick buffers |
| Product | Port technology for steering elevators (optimization of people's transport) |
| | Product related app |
| | Spare parts printing |
| Service | Value added services (holistic services) |
| | Supervision of elevators (maintenance etc.) |
| | Simulation for new network design |
| | Flexible network optimization |
| | Automatic network management |
| | Risk Management |
| | Compliance Management |
| | B2C e-commerce: expand automatic recommendations for fashion clients to reduce returns |
| Quality | Secure delivery performance towards the customer |
| | Last mile delivery |
| | Goods receipt and goods issue via RFID |
| | AR/VR in the warehouse |

| | |
|---|---|
| | Automated guided vehicle in the warehouse |
| | VR for maneuvering |
| | Spare parts/machinery availability |
| | Connection of machines (machines communicate among each other) |
| Choice option | Individualized steering of shipments |
| Planning | Sales forecast (logistics demand forecast) |
| | Data analysis, big data, predictive analytics |
| | Operations research forecasting models |
| | Planning of capacities (e.g. warehouse structures), demand forecasting |
| | Estimated time of arrival forecast (geofencing) |
| | Optimization timetable transport |
| | Advanced forecasting (better supply for point of sale) |
| | BIM data for forecasting |
| | Analytics for capacity management |

The strategies highlighted are those chosen by the groups to be presented in the open panel (phase 2). Table 12 displays the result of the voting round (phase 2) for the six prioritized strategies.

**Table 12:** Nominal group technique's prioritized strategies (Phase 2)

| Strategies | Points attributed |
|---|---|
| Forecasting (demand, sales, …) | 32 |
| Reduction of media discontinuities | 15 |
| Last mile delivery | 11 |
| Estimated time of arrival forecast (geofencing) | 11 |
| Smart container (live tracking for customers: GPS and temperature) | 9 |
| Secure delivery performance towards the customer | 6 |

### 6.2.3 Discussion

**General observations**

Some of the proposed strategies are highly related to specific products (e.g., seeds or elevators, autonomous train clutching) and are therefore difficult to generalize. The distribution of strategies proposed shows a clear focus on information disclosure, service, quality, and planning/forecasting, which was introduced as an additional performance component based on the results of the NGT workshop.

### Information disclosure

The strategies mentioned in this cluster mainly concern tracking and tracing solutions as well as new communication platforms with customers. Tracking and tracing goes beyond typical GPS tracking and also includes additional information (e.g., temperature). Integration into driver apps and customer portals was also mentioned. These tracking and tracing solutions connect manufacturers, logistics service providers, and customers and aim at providing real-time information. The requirement for providing end-to-end-information is also recognized Apps are proposed for close and direct communication with customers, thus providing mobile solutions for interaction.

### Time

It is difficult to draw a hard line to distinguish between strategies for the performance components time and quality. The proposition here is that automatized processes fall into the time component, whereas the application of technologies such as AR/VR improve the quality of value creation. However, the time-related strategies also intend to improve quality and vice versa. This should be kept in mind when assessing the strategies. Time-related measures mainly account for optimizing throughput time by automated material flows and preparation of orders for picking.

### Product

There are surprisingly few product-related propositions within the NGT workshop, which leads to the assumption that practitioners currently do not yet fully recognize the potential of hybrid service bundles. However, they proposed product-enhancing apps, new ICT for improving products, and additive manufacturing for spare parts.

**Service**

A range of value-added services was proposed by the panelists, which included risk and compliance management, network optimization and supervision. These services might be combined with, for example, maintenance recommendations.

**Quality**

As previously mentioned, the distinction between quality and time is not always clear. The propositions include assuring delivery performance, optimizing quality of processes in the warehouse, and providing production stability through assuring machine availability.

**Choice option**

The sole strategy proposed here is individualized shipment options.

**Planning**

Planning, which includes forecasting, is added as an additional performance component as many strategies were mentioned for this cluster. They range from sales to estimated time of arrival forecasts and aim at better using capacity. This provides a better planning base internally as well as externally and hence can create more reliability in L&SCM networks. It is noteworthy that the measures proposed are based on predictive analytics. The step towards prescriptive analysis to create actionable insights seems not yet to be on the agenda of the workshop participants.

**Values**

From the strategies proposed, a clear current prioritization can be deduced.

Value of availability > Value of servitization > Value of integration or co-creation

Value of cognition is sometimes inherently captured but seems not to be in significant focus except for some proposed strategies such as recommendation services.

The final voting round prioritized three clusters that the experts deemed to be most important. The first one is forecasting (sales, demand, and estimated time of arrival), the second one is assuring (last mile) delivery reliability, and the last one is information disclosure by tracking and tracing solutions that require the reduction of media discontinuities.

The following section pools the findings of this chapter and proposes a recapitulatory conceptual framework to include them.

## 6.3 Theoretical framework

The proposed framework in this chapter builds upon Figure 16 as well as the findings of Chapters 5 and 6. The underlying objective for the framework is to provide an aid for conceptualizing in order to generate more customer value adding L&SCM strategies based on DT technologies. Although the framework builds upon the previous elaborations presented in this thesis, the processes that are impacted by DT and affect end-to-end L&SCM such as transportation and risk management are not exhaustive.

Furthermore, the framework does not explicitly account for innovation and leadership strategies to create more customer value, which are constituents of DT in L&SCM but are not part of the focus of this thesis.

The aim of the framework is to provide conceptual guidance for researchers and practitioners. Practitioners are enabled to structure their DT initiatives and to identify the impact areas. It can be used to develop fact sheets about initiatives and for describing relations along the end-to-end L&SCM network through to customer orders. Researchers can gain insights about the constituents of customer-based L&SCM performance components based on DT technologies and can use the framework as a starting point for investigating relationships among initiatives and linking them to customer value strategies as well as components, contexts, and outcomes. The outcomes are directly linked to KPIs (typical ones as well as new ones as proposed in section 6.1.3). In order to be useful, the KPIs should be linked to the value creation strategies as well as the underlying technologies to understand the impact of DT technologies in L&SCM networks. In further steps, the role of people as orchestrators of (partly) autonomous L&SCM networks needs to be understood more clearly.

The framework serves as a basis for the expert interviews in Chapter 7 that investigate the success factors, impacts, and paths of the customer value adding strategies in manufacturing companies.

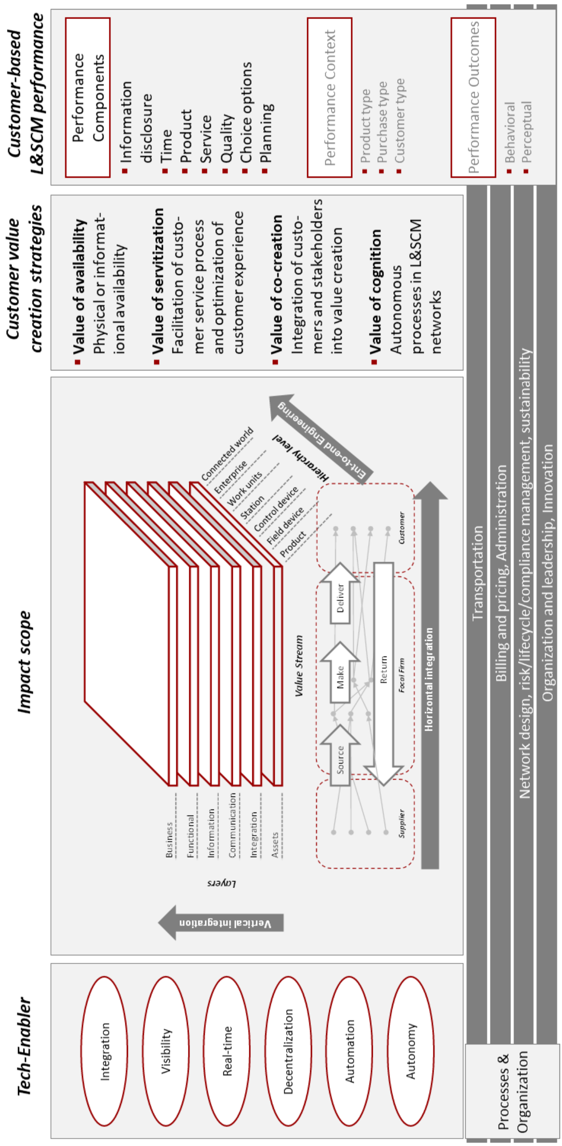



**Figure 29:** Impact on customer-based logistics and supply chain management performance

## 6.4 Summary

The chapter first provided a definition-based approach to customer value in L&SCM by describing performance differentiation and then linking this to the capabilities of DT technologies. This led to establishing the "three plus one" values enabled by DT technologies: the values of availability, servitization, and co-creation, plus the value of cognition as enhancement. Customer-based L&SCM performance can be clustered into components, context, and outcomes. For the further progress of this thesis, the focus lies on components rather than context and outcomes. These components can, based on the literature, be differentiated by information disclosure, time, product, service, quality, and choice options. It should be noted that the distinction between products and services is increasingly disappearing as products are equipped with intelligence and hybrid service bundles represent both products and associated services.

The NGT workshop that followed revealed strategies and measures for adding customer value in L&SCM. Based on the findings, the L&SCM performance components were enriched by planning and forecasting. The prioritizations of the participating experts showed that, currently, the value of availability is more important than servitization or co-creation.

The findings provided additional constituents for the presented recapitulatory conceptual framework, which serves as a basis for the expert interviews presented in Chapter 7.

# 7 Capturing customer value in logistics and supply chain management

This chapter builds upon the previously elaborated findings and enlarges them. To achieve this, first, the three plus one values that were identified in Chapter 6 are put into the context of an overall DT strategy in logistics by investigating how projects are embedded into a wider strategy of innovation management and organization. This is done through a series of expert interviews.

## 7.1 Expert interviews

The expert interviews are presented in the following manner. First, the methodology is described; second; the cases are introduced; and finally, an in-depth analysis of the findings is performed.

### 7.1.1 Methodology

The conducted expert interviews are explorative in nature and support pre-theoretical knowledge gain.

Preparation for the interviews was based on the propositions and recommendations of Mayer (2013) for semi-structured interviews. Following Mayer, the interview does not have to follow the exact procedure outlined in the guideline, but all questions and sections proposed should be answered to assure comparability and a valid basis for data evaluation. The semi-structured interview also allows the interviewer to ask further refining questions when, for example, an interesting topic or approach is mentioned and therefore offers the possibility of deepening certain findings.[215]

The procedure for preparing, carrying out, and analyzing the interviews rests on the approach set out in Figure 30.

[215] Cf. Mayer 2013, pp. 37ff.

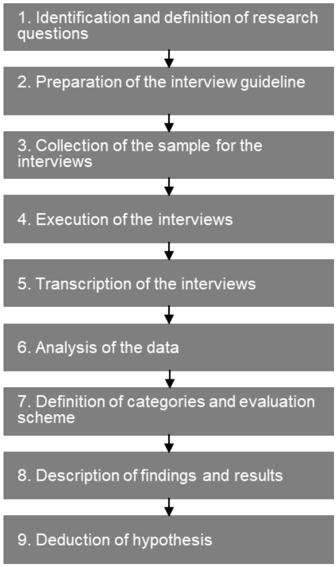



**Figure 30:** Methodological approach expert interviews

This approach lacks a pre-testing of the semi-structured interview guideline. However, at the end of each interview the interviewees were asked whether they could see clear points missing in the guideline and what points they would like to add. Additional remarks were included but the feedback from the interviews did not add additional dimensions to the interview guideline. Next, the process for preparing and conducting the interviews is described in more detail.

**1. Identification and definition of research questions and themes to be investigated**

The first step for identifying and defining the research questions for the expert interviews follows the approach by Lee and Saunders (2017) for constructing a critical analysis. This includes developing an overview of the key ideas and themes in relation to the research. The next steps are to make notes to summarize, compare and contrast the key ideas and themes. To further narrow down the research aim, more in-depth reading and making notes of the ideas and themes that appear most relevant for the research is required. Then the aspects where more insight is needed should be identified and the reasons for that should be noted. Following this procedure, the research questions that provide those insights should be stated.[216] The identified research areas build upon the findings of the previous chapters.

The three areas under investigation are

I. Strategy for DT in L&SCM;

II. Projects within the identified 3+1 values (see Chapter 6), including open innovation and organizational changes; and

III. Recommendations and success factors.

These three areas move the analysis toward the goal of deducing the building blocks of how successful manufacturing companies capture the customer value of DT and what might be changing in the role of L&SCM as well as the measurement of performance (KPIs).

**2. Preparation of the interview guideline**

The complete interview guideline can be found in Appendix C. Overall, the interview guideline is designed in such a way that the interview duration is about 60 minutes, the three areas are sufficiently covered, and there is room for the introduction of the topic and the underlying definitions as well as follow-up questions. This approach resulted in a questionnaire consisting of 16 questions (see Appendix C).

[216] Cf. Lee and Saunders 2017, p. 68

### 3. Collection of the sample for the interviews

In contrast to quantitative questionnaires, qualitative expert interviews follow a different logic for sampling. For expert interviews, the relevance of the expert's knowledge is decisive for the eligibility for participating in the interview. Eligibility for the sample for this thesis consisted of the following criteria: the company must be advanced in the topic of DT in L&SCM; and the interviewee must have sufficient experience in L&SCM (represented by years of professional L&SCM experience).

Table 13 sets out the job descriptions of the experts enrolled in the interviews.

**Table 13:** Job title participants expert interviews

| Case | Job description |
|---|---|
| A | Digital Strategy for the production site |
| B | Senior Vice President – Head of Logistics |
| C | Senior Vice President Operations |
| D | Vice President Logistics |
| E | Head of Digitalization and Concept Development |
| F | CEO |
| G | Head of Logistics |
| | Head of Production Planning and Scheduling |
| | Head of Logistics Planning |

An additional criterion was that the company needs to manufacture in multi-variant series production. The interview sample consists of large companies, because research has shown that they are more advanced in their technology deployment.

### 4. Execution of the interviews

The interviews were conducted face-to-face or via telephone between September $30^{th}$ and December $11^{th}$, 2019. The mean duration was 63 minutes.

**5.** After **transcribing** the interviews, the data was **analyzed and evaluated (6) and (7)**. The **findings** are presented subsequently **(8).**

### 7.1.2 Case descriptions

**A**

Case A covers aerospace as an industry. The turnover in 2018 was 64 billion euros and the number of employees for the whole group amounts to 150,000 (2018). The production site where the interviewee is based has 16,000 employees but the answers relate to the end-to-end L&SCM network covering all production sites as well as suppliers. The interviewee holds the position of Digital Strategy for L&SCM for the respective production site and can look back on six years of L&SCM experience including organization of transport logistics and as well as logistics within the production sites. The customer served comprises the internal customer, the production sites, as well as some external customers delivering into the production process, which involves around 300 components. The B2B network can further be described by 2,800 nodes, mostly without consistent end-to-end relationships, and different transport modes (air, water, road) as well as internal transportation.

The main challenges are data quality and security as well as transparency about customers. It is often unclear where customers stand, so delivery reliability and risk management can be difficult. The industry is rather risk-averse so protection of personal and business-related data is an issue as strong safety requirements prevail, which stands in contrast to the approach of companies such as Tesla , which are opening all their patents.

**B**

The second case (B) is from the plant engineering and energy industry. The company is mainly involved in gas and power, switchgear, and transformers. It is a heavy-duty industry with special requirements for transport. The turnover of the mother company was 83 bn. euros for 2017/2018, the number of employees in total is 379,000 (2017/18) and for the energy division alone, which is becoming an independent company, the employee headcount is around 80,000.

The interviewee has worldwide SCM responsibility for the energy division and he has 20 years of procurement and SCM experience. His position is directly under the board of directors. The customers are B2B key account customers. They are large customers mainly being supplied with turnkey plants.

**C**

Case C produces devices for the home appliance industry and belongs to the electronics sector. In 2018, the organization had a turnover of 2,791 bn. euros and 12,972 employees. The position of the interviewee is Senior Vice President Operations. His responsibilities include all L&SCM duties: planning and transportation, warehouses, parcel, and last mile. In addition, there is another logistics department for the production entities that includes operative and strategic purchasing for production. The customer is L&SCM for the company itself (B2B) as well as serving external customers including distribution (B2B and B2C).

**D**

Case D has 60 % of its revenue in the automotive industry and 40 % in electronics, home appliances, thermotechnology, security technology, and building technologies. They had a turnover of 78 billion euros in 2018 and 410,000 employees worldwide. L&SCM represents 28,000 employees. Logistics costs amount to about 8 % of revenue across all sectors (transport, warehousing, warehousing management). The logistics costs have decreased since 2013 (from 9.5 to 8 %) and logistics has been centralized since 2013 (e.g., warehouses). Furthermore, a new transport management system for steering and optimizing in-house routing has been introduced.

The interviewee has 25 years of L&SCM experience and is mainly responsible for inbound logistics, warehouses, intralogistics, and outbound logistics. A large amount of inbound logistics is Free Carrier. The L&SCM unit operates around 600 warehouses, including both warehouses operated by external logistics service providers and self-operated warehouses. Intralogistics covers production supply, internal warehousing, goods receipt, and outgoing goods. Outbound logistics is mainly automotive Free Carrier by customers, but China is an exception where Delivered At Place and Delivered Duty Paid is applied. For the non-automotive sector, outbound logistics is very heterogeneous.

**E**

Case E is from the automotive industry. The interviewee's position is Digitalization and Concept Development for material logistics. He has 20 years of L&SCM experience and has been responsible for inbound logistics for seven years, and digitalization and concept development for two years. The position for digitalization and concept development was newly created two years ago. Employee headcount in the unit "Digitalization and concept development" is 40 people and will rise to 50 staff in 2020.

The L&SCM unit serves the company's 122 production sites including their intralogistics processes. The digital service offered by the unit "Digitalization and concept development" will help them to increase their efficiency. Additional customers are external partners, forwarders, and LSPs, which are provided with service activities and are assisted in improving their business and processes. Concerning outbound logistics, customer requirements determine the logistics service and performance.

**F**

Case F is a company that consists of two parts: one is L&SCM as a service and the other is car body construction (Tier 1 supplier). The logistics activity employs

20,000 employees at 72 sites worldwide and their revenue in 2018 was 1.3 bn. €. The key focus is the automotive industry, with very few exceptions. They offer services to the big automotive OEMs (e.g., VW, Daimler, BMW, Land Rover, GM, truck manufacturers, Fiat, etc.). Key activities include inbound logistics and packaging. Packaging for the automotive sector mainly involves packing parts for export from Germany, but also for shipping from America or India back to Germany. In the inbound logistics function, they provide the classical supply requirements for customers (goods receipt, storage, and picking) to deliver parts JIS for the production line. The other activity is assembly, representing almost the same steps as inbound logistics activities but with one additional value-generating step. In assembly, complete modules such as door panels or exterior mirrors are delivered to the production line.

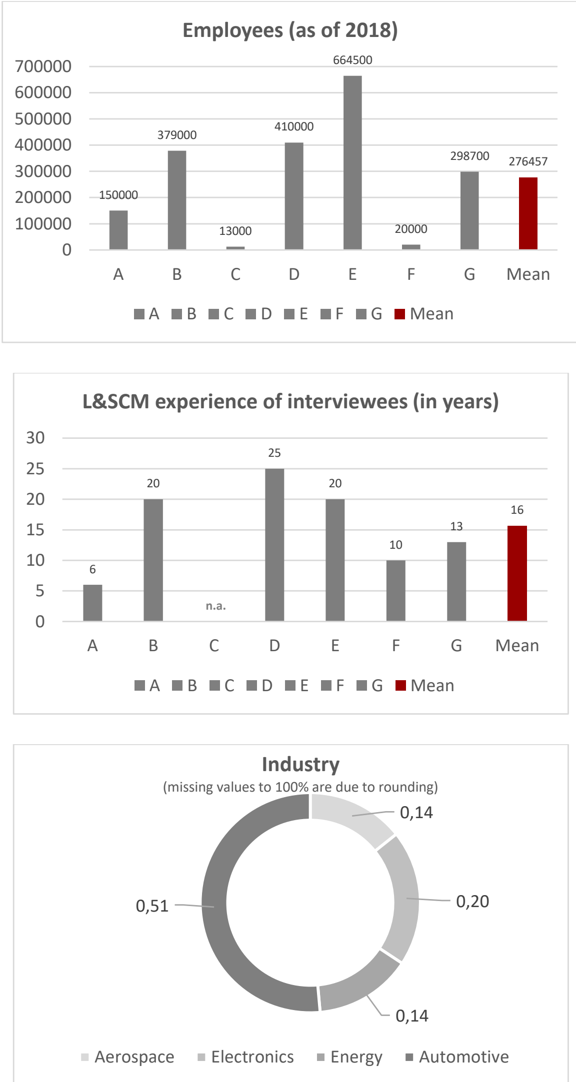
In 2016, the company created a special unit dealing with digital innovation. They decided that DT might have a decisive impact on the company and hence created this unit. This unit is not concerned with operational activities so that it is able to focus on DT from a strategic angle. The unit was founded in September 2016 and the target is to scan the market to understand what start-ups, competitors, and suppliers are doing. They also evaluate the implications on their business model and the resulting adaptations and developments needed. Thus, they try to foresee the development of their business model and assess which other business models need to be developed (e.g., new services). The focus is on innovation management, which includes trend scouting and technological pilots within the company. If a pilot is successful, rollout starts and is deployed in production.

The interviewee has around 13 years of L&SCM experience and is the head of the company's digital innovation unit.

**G**

The last case (G) also covers the automotive industry. The production site in focus builds 50,000 transporters per year and internal costs are 250 mn € per year. The site employs 2,000 people. The mother company employs 298,700 people worldwide and had a revenue 167 bn € in 2018. The interviewees were three participants: the head of Logistics of the plant, who is also a member of the plant's board (8 years of L&SCM experience), the head of production planning and scheduling (14 years of L&SCM experience), and the head of logistics planning (18 years of L&SCM experience). Their customer is the associated plant and its L&SCM including assembly, paint shop and carcass.

Figure 31 summarizes the interview sample.




L&SCM Logistics and supply chain management

Note Value of L&SCM experience for the interviewee of case C is not available.

**Figure 31:** Sample expert interviews

Concerning the self-assessment of the status of DT in L&SCM, most participants rated their organizations between 4 and 5 on a scale of 1 to 10 (where 1 = not yet started with DT activities and 10 = very mature, transformation completed). It was mentioned that Amazon, in comparison, would be a 9 and that consistent connectivity is still lacking.

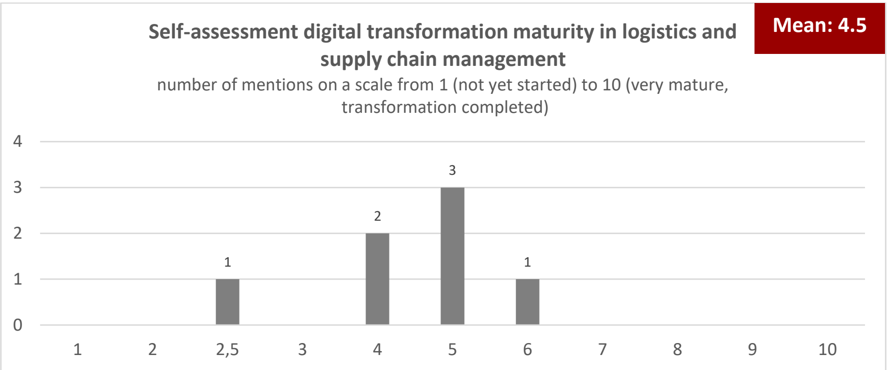



**Figure 32:** Digital transformation maturity in logistics and supply chain management

As the word transformation is inherent in DT, it describes a change at a certain stage. For DT that is ongoing, and the fact that the highest ranking is a six also reflects that there is no maturity yet. The following sections describe building blocks of DT in L&SCM based on the expert interviews.

### 7.1.3 Findings

First, the overall strategy for DT in L&SCM is depicted, followed by projects that capture the 3+1 values described in Chapter 6. Subsections 7.3.3 and 7.3.4 describe the enablers of open innovation and adaptation of the organizational structure. Success factors conclude the findings and then lead to a framework for approaching DT in L&SCM (7.5).

#### 7.1.3.1 Strategies for digital transformation

All interview participants have a dedicated strategy for DT in L&SCM in place. In general, the companies have a global digital vision and strategy, of which one part is the strategy for DT in L&SCM. Early adopters started to work on such a strategy in 2013, although the first ideas already existed in 2009. Most of the interview participants set up their dedicated strategies between 2015 and 2017. Starting points were the digital integration of suppliers and forwarders in ICT systems, digitalizing freight clearing, scanning the transport process to find bottlenecks, and fixing media discontinuities.

Visions for 2030 for L&SCM exist but are still not very concrete. In three cases, there is a clear strategy and vision for 2025 or 2030, whereas it is obvious that the strategic focus lies more in the timeframe up to 2025. Concerning 2030, one of the interviewees stated: *"We find ourselves in a research environment."* An example with a concrete vision for 2025 sets two main priorities. The first one is to increase transparency in the transport process and the second one is to automate administrative tasks.

Only one participant mentioned the relationship to organizational development and employee and skills development. However, these factors are emphasized more clearly when talking about success factors for DT in L&SCM (7.1.3.6).

The organizational anchoring of DT activities for L&SCM within the organizations does not follow the same pattern but can be summarized by four characteristics: either under operations, within corporate SCM, directly with the plant manager, or organized as a special unit without operational responsibility. The four characteristics are displayed below:

- logistics and transport as part of operations (e.g., plant/operations manager as responsible person or the respective logistics manager for the operation company with support from corporate and IT)
- corporate SCM together with service unit and the business units (restructuring toward a service organization)

- special unit DT within corporate SCM in collaboration with IT (they are product owners of the digital solutions)
- special unit with strategic focus, without any operational responsibility, reporting directly to the board of managers.

In three cases, L&SCM and therewith the responsibility for DT in L&SCM is part of operations and in two cases, it is corporate L&SCM (see Figure 33).

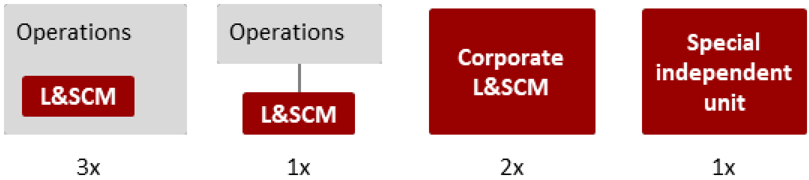



**Figure 33:** Organizational anchoring of logistics and supply chain management

Two important prerequisites for successfully approaching DT in L&SCM are agility and openness for data sharing (refer to Figure 14). The next paragraphs summarize the status quo as described by the interview participants.

**Agility**

The self-assessment about being agile varies between participants, although it is clear that the majority of the interviewees see themselves as being agile toward customer requirements. But it is also clear that large companies can only be agile to a certain extent, as the company size hinders agility. For the participants stating that they see themselves as being agile, they think that this is a prerequisite. Small and venturesome sites can serve as lead users.

For the participants who were undecided whether to assess themselves as being agile, this was owing to a number of factors.

They stated that externally they are rather agile. In contrast, internally, for deploying new solutions with a strategic orientation, they rate themselves as being rather non-agile. Also, long-existing contracts (e.g., with suppliers) are often not in a state that is amenable for DT projects.

One participant stated that agility is not possible owing to the large company size. Agile methods help to develop prototypes and solutions more quickly. However, deploying them in the line organization takes more time.

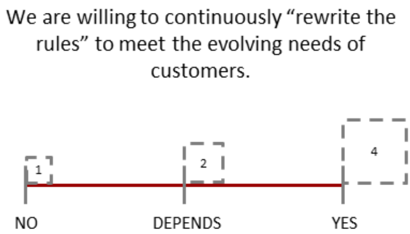



**Figure 34:** Self-assessment "Agility" (number of mentions)

## Data sharing

Overall, there is a development toward being more open when the benefit of sharing data is clear. The interview panel also reflects this, as 57 % state that they are open to sharing strategic information with their SC partners. This is operationalized through clear guidelines for classifying and sharing data.

Participants build and run their own, private clouds for sensitive and processed data and create open data lakes to make data available. Data lakes are big data repositories that store raw data and provide functionality for on-demand integration with the help of metadata descriptions. Data lakes contain raw data in its original format from heterogeneous data sources. They serve as storage repositories and allow users to query and explore data. Metadata management is very important for data reasoning, query processing, and data quality management. Without any metadata, the data lake is hardly usable. Structure and semantics must be known in order to turn the data lake into a valuable resource.[217] The interviewees

[217] Cf. Hai et al. 2016, p. 2097

state that formats for benefiting from shared data are, for example, digital rate cards for framework contracts. They stress that data sharing settings rely heavily on the respective case and that strategic, trustful partnerships are a key success factor.

Data sharing along the end-to-end SC is still up in the air. One participant stated: *"We already deploy quite consistent data models and are willing to share data. We started with Tier 3 until OEM, but now the focus is more on Tier 1 and OEM."*


**Figure 35:** Self-assessment "Openness for data-sharing" (number of mentions)

To summarize, openness to data sharing becomes more important as the significance of trust in business relationships grows. Openness to data sharing is more widespread if new business models are created. Data sharing in "traditional" setups where interfaces are hardened seems more difficult. The benefit for all stakeholder needs to be clear (costs/collaboration/structures). Data ownership, flow, and use must be specified. Then all services and solutions are made available in the cloud. One statement clearly shows this: *"Basically we try to bring all our solutions into the cloud, whether it is our own or an external one such as AWS[218]/Azure."*

Trust in business collaborations becomes ever more important, which is reflected by the following statement: *"If we have a trustful relation with a customer we also share critical data describing a USP."*[219]

---

[218] Amazon Web Services
[219] Unique selling proposition

#### 7.1.3.2 Capturing values of availability, servitization, co-creation, and cognition

**Assessing customer requirements**

For assessing actual customer requirements, a brief summary of the interviewees' perspectives follows.

Current problems still concern information silos. For the internal customer, the production sites, the focus still lies on optimization by department, so sharing of production status takes place once a part is finalized and not necessarily during production. Concerning the supplier perspective, this means that often they are not willing to share everything they can influence their production. One participant mentioned: *"I would like to be more transparent about our own production status, but some people don't like to hear this. Because of high system inertia, flexibility is not yet given."*

Under such circumstances, it might be difficult to offer customized L&SCM solutions, which can represent a strategic competitive advantage. Good L&SCM is often assumed as standard, so it can be difficult to make customers perceive exceptional L&SCM as a differentiating factor. The tendency is that individualized L&SCM becomes more important with increasing complexity and special requirements of the projects.

Opportunities and solutions from interview participants to assess customer expectations touch different aspects. One participant stated that the services offered create new customer expectations that are met and hence help to assure customer retention. Different channels are used to assess customer requirements, for example, one for setting up a new customer project determining delivery frequency, incoterms, communication via electronic data interchange, or other interfaces; and another one for ongoing projects. For running projects, a customer requirements server can bundle technological and logistical requirements, which are established the point of sale, can then be evaluated and fulfilled or rejected.

For requirements in the production network, best practices are identified and knowledge exchange is encouraged.

The evaluation of projects among L&SCM partners relies on classical KPIs and is mainly determined by costs. Tier 1 suppliers get constant feedback because they are in direct interaction with their customers. Additional sources are calls for tenders and news about their customers. Classical customer management supports this evaluation. Determining factors remain cutting costs and reducing time while maintaining quality. Expectations are determined by yearly budgetary targets and are adapted throughout the year. Because of the KPIs in place, *"the expectations from the production sites are cost-driven."* For outbound logistics, customer requirements clearly determine the service and performance.

To summarize, the assessment and tracking of customer expectations is still rather "traditional." Please also refer to Chapter 6.1.3, which describes how classical KPIs might evolve. The following, paragraphs describe the ongoing and future projects concerning the 3+1 values for customer-based L&SCM based on DT technologies.

**Value of availability**

Current projects for increasing availability in L&SCM networks cover mainly surveillance.

On the supply side, they cover digital quality management and forecast improvement toward the 2$^{nd}$ tier supplier. For raw materials, for example, this means determining which intelligent forecast and delivery frequencies and modules can be integrated via interfaces and how they can be linked with automated quality checks.

Track and trace, as far as original equipment manufacturers are concerned, still focuses mainly on inbound logistics, but now also includes end-to-end surveillance about material flows between production facilities. This does not exclude monitoring of material within the production facilities – interview participants are currently building a digital twin of their own production. The vision of the digital twin has evolved during the last decades and describes the vision of a bi-directional relation between a physical artefact and the set of its virtual models. This virtual "twinning" that describes the relationship between and representation of the physical objects and their virtual models helps to improve the efficiency of execution of product design, manufacturing, and servicing across the product life cycle. Barriers to implementation include insufficient possibilities for synchronization between the physical and the digital world to establish closed loops; the absence of high-fidelity models for simulation and virtual testing; the lack of uncertainty quantification for such models; the difficulties in the prediction of complex systems; as well as the challenges for gathering and processing large data sets.[220]

For increasing the availability in networks, the focus concerning transportation is on bundling loads in order to reduce empty trucks and increase full truck load. Furthermore, the transportation process is simplified by creating a consistent digital transport file. Once this is established, different services can be offered, such as dynamic delivery windows for trucks, automated invoicing, and paperless transport.

For warehousing, standardization processes are implemented to improve availability and reduce inventory by standardizing warehouse management systems.

The currently biggest focus lies on making not only flows of materials transparent, but also those of their containers. Container management with smart containers, which saves empty container inventories and yearly inventory checks at suppliers,

[220] Cf. Schleich et al. 2017, p. 142

augments availability and allows for granular tracking, which is important to detect bottlenecks and react accordingly. A challenge is to equip all containers with intelligence (e.g., RFID) group wide.

Future projects build on the ones described above but aim at creating consistent availability across the value network. Consistent track and trace to know exactly where goods are located at any time will allow for better capacity planning about staffing for, for example, goods receipt. Future digitalization of customs documentation will reduce costs.

Internal projects build upon the digital twin in production. These projects include a planning tool to increase planning quality and flexibility through real-time data about availability. Until now, this is an internal tool without connectivity to suppliers, but it is planned to link it to other SC partners. This is reflected in the statement: *"We have a seamless documentation of our components, but our suppliers don't. We have to extend this information in the SC. So, a future development will be that suppliers need to make data available related to the components."*

To increase availability in L&SCM networks the projects follow a certain logic:

Stage 0: Collection of all data describing the flow of goods in the network takes place.

Stage 1: Data is connected.

Stage 2: Manual steps are supported by digital information.

Stage 3: Manual or paper-based processes are replaced by digital information and automated execution.

Overall, the tenor is that technologies and data clearly help to improve availability in L&SCM networks, but sometimes there are also overestimations: *"There has been a huge hype about condition monitoring, this for us is only relevant for a few parts."*

The focus for the value of availability lies on surveillance and forecast.

**Value of servitization**

The current projects about new services in L&SCM partly build upon increasing availability in L&SCM networks.

New services are based on data lakes, for example, spare parts management for customers. The aim is to synchronize the operations of customers and the focal firm.

Internally developed transport management and track and trace solutions (e.g., for containers) are offered externally once they are tested and verified. This also concerns the dynamic steering of inbound delivery with trucks using an appropriately developed electronic data interchange message solution to give recommendations.

Services for internal deployment and diffusion are about assistance systems for production sites. Critical path analysis and tools to determine the estimated supply range to support material requirements planning via one central web interface. Further projects include planning support from an L&SCM perspective for ramp-up and ramp-down phases.

For administrative tasks, automated invoicing is offered as a service.

Another service field is technology assessment for DT technologies used in L&SCM. One participant stated that they offer a service for component recognition, including technology assessment and deployment. Currently, three technologies exist: RFID, QR code, or camera based.

For future projects, participants stated clearly that everyone is aiming to develop services based on data, which means the extension of Logistics as a Service.

One future project focus is deploying a control tower for a new organization for disposition. This control tower will help to bundle all relevant supply-related information and free human planners from troubleshooting activities. It can also alert in case of deviations. It would also be possible to integrate information from forwarders' transport management systems to receive processed estimated time of arrival and offer them dynamic ramp-up planning and steering. Based on control-tower data, further analytics solutions can be implemented, for example, communication with a chatbot.

Future services for warehousing include carrying out inventory checks using drones equipped with camera systems and predicting how many containers will be empty based on the production program and other factors. This will lead to a dynamic warehousing strategy that can also be offered as a service.

Dynamic planning of employee staffing and planning of sequences with greater consideration of demand are further examples that were mentioned as new services at the intersection of production planning and L&SCM.

The tendency is that services are developed internally, financed by avoided quality-related costs, and are then offered externally. The challenge is to translate these services into a business model and/or revenue streams (e.g., pay-per-use).

> For the value of servitization, the focus is on the development from static to dynamic planning as a service, as well as technology assessment and integration as a service and the automation of administrative tasks.

**Value of co-creation**

In 2017, the status of co-creation was that Industry 4.0 presented opportunities to drive forward the customer focus by integrating smart products. The internal logistics network can in addition be supported by products that allow the customers and suppliers to intervene in the value creation process. As of 2017, no activities could not be identified relating to intelligent products with inherent sales order data. Customers are conventionally integrated via sales or after-sales, but not into internal processes.[221]

From the findings of the expert interviews concerning, co-creation participants tend to work more closely with suppliers than with customers.

Co-creation includes, among other activities, the joint development of warehouses with suppliers. For production sites, co-creation concerns ambiguous assistance systems that are always developed collaboratively with the producer.

The concept of the "extended workbench" includes warehouse operations or additive manufacturing at the customer without the need to ship the part.

Co-creation also forms part of services such as "trunk delivery" to field service technicians' vehicles. This has been operational for a decade but is now supported by better forecasts.

Some planned projects already tend to integrate the customer more closely in the value creation process. They aim to integrate data about the customers in order to improve processes. Customers provide data about product use, which in return is used to improve SC processes, for example, capturing movement profiles or the exact method of handling products.

It has been observed that co-creation shapes a target picture in a collaborative manner and helps in assigning the right tasks to everyone. The challenge lies in the different maturity levels, capabilities and priorities of co-creation partners. Interviewees agree that trust is the most decisive success factor for co-creation.

| |
|---|
| The focus for the value of co-creation is on the extended workbench and assistance systems. |

[221] Cf. Roy 2017, p. 120

**Value of cognition**

Current projects focus on optimizing subprocesses where the additional value created is essential. This includes bots for simple tasks, route optimization (e.g., determination of hubs), prescriptive demand management, and image recognition.

Another area of current interest is preparing support projects, such as those to completion the collection of missing data (e.g., incomplete master data).

Interviewees also mentioned projects for internal production, such as an internal production planning tool that autonomously determines alternative solution paths, or the connectivity and integration of automatic guided vehicles.

Original equipment manufacturers are also starting to link behavioral aspects of the product in use to the production line and maintenance intervals, where machine learning is applied.

In the future, the aim is to synchronize local optima to reach an end-to-end optimum, for example, by using agent-based systems. Accomplishing this condition is still seen as being several years in the future. This requires linking internal production planning and forecasting tools to other SC partners (e.g., Tier 1), which is planned to be introduced by 2025.

In the future, the decision support systems might (partly) serve as execution systems, but this is not currently the case, as reflected in this statement: *"Currently we are at a stage where we see the learning algorithms as decision support systems and not as execution system."*

There is a consensus that the greatest potential value can be obtained if all system-determining factors are integrated, but integrating them all still poses a significant challenge. The assumption is that preparation activities in logistics (e.g., disposition) will become redundant because they will be taken over by machine learning. Employees will instead be concerned with process improvement and coping with tomorrow's problems.

The focus for the value of cognition currently lies on local decision support systems and will probably evolve to (semi-) autonomous end-to-end execution systems.

Figure 36 summarizes the foci of the 3+1 values based on DT technologies on which the interview panel's organizations are currently focusing. It must be remembered that, owing to the sample size, the panel is not representative for any industry.

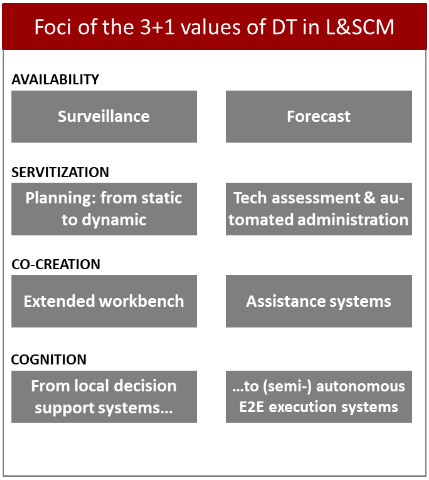



**Figure 36:** Foci of the 3+1 values of digital transformation

#### 7.1.3.3 Evolution of key performance indicators

Participants were not in complete agreement concerning the evolution of KPIs. The interviewees stated that KPIs will probably evolve and measurement will become more granular due to increasing data availability. This is especially relevant for increased planning speed and planning accuracy. This can impact the area of quality. Inventory measurement could shift to a stronger focus on the cash flow effect.

There was a suspicion that some KPIs will vanish; for example, delivery reliability as it concerns time windows, because this will become dynamic. Therefore, it can be deduced that changing processes will also change KPIs.

However, proponents of traditional KPIs stated that measurement of the classic L&SCM KPIs has not changed and will probably not change because of the introduction of new technologies. *"I think it is not clever to skip the classical L&SCM KPIs."*

Overall, the interviewees agreed that the decisive issue will remain that of costs. However, they also mentioned the prospects for new KPIs. These include the measurement of human-machine interaction, plus the exact execution of tasks; master data quality; and system availability. KPIs to measure sustainability in combination with DT technologies are not yet in focus. For further prospects for customer-centric KPIs, please refer to section 6.1.3.

The following statements provide an impression of how the interviewees see the evolution of performance measurement in L&SCM:

- *"We need to understand way more, how people accomplish tasks."*
- *"KPIs are always suspect to change but it is essential to use the KPIs that are important for the planning and steering of L&SCM processes. Less is more – applied with a great deal of consequence."*
- *"I must admit that we do not yet have a view on the intersection of DT and sustainability."*

It must be acknowledged that modelling for a high number of variants is more complex, but the expected benefits of more sophisticated and more granular KPIs can outweigh this upfront expenditure.

To summarize, the presumption is that new processes will change KPIs in the future but, at the current stage of development, new KPIs have not yet been formulated.

#### 7.1.3.4 Open innovation

The interviews indicated that open innovation, if applied, still focuses more on product development rather than L&SCM. It takes the form of, for example, the creation of a special entity for DT concerning product innovation.

Interviewees stated that institutionalization is rather difficult and depends on the specific case. The interest in more targeted, open innovation activities for L&SCM is there, but activities to date are mainly related to market screening and some co-creation pilots. Tools and methods applied are internal labs and accelerators, which already exist for production engineering and logistics; innovation events at external labs (e.g., DHL Lab in Köln, Digital Hub Hamburg); and visits to Silicon Valley, China, and Korea.

Two of the interviewees organize regular innovation days that include external partners. This market screening is complemented by trade shows and joint projects with academia, including PhD students. In addition, regular exchanges take place, for example, with logistics service providers' innovation managers, and there is co-operation on pilot projects and start-ups.

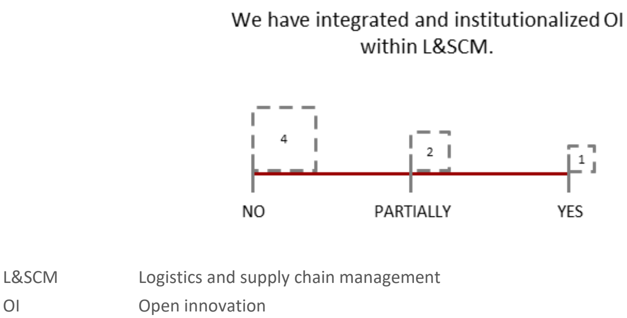



**Figure 37:** Institutionalization of open innovation (number of mentions)

One interviewee mentions: *"We are protectionist, but actually sometimes we do not know why and what to protect exactly."* The interview results confirm the evolution that Figure 38 depicts.

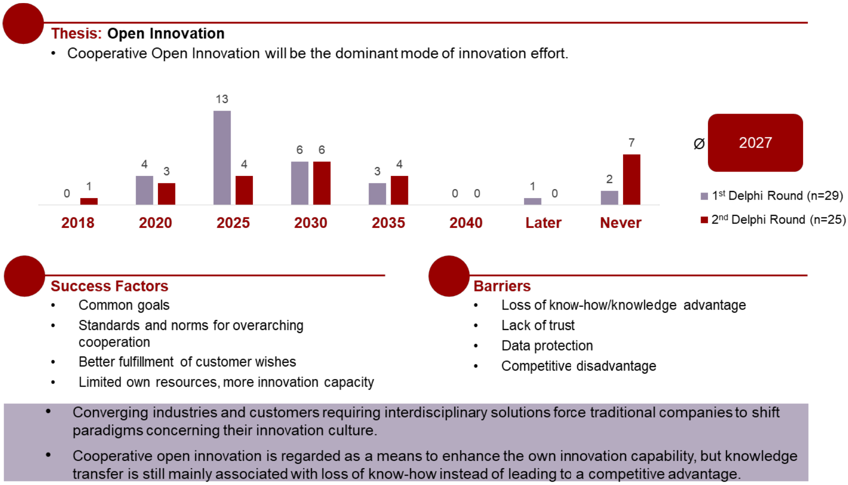


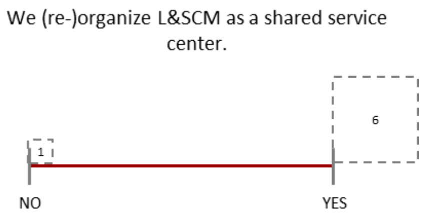

**Figure 38:** Cooperative open innovation in L&SCM[222]

As open innovation is rarely integrated with L&SCM, there is an opportunity to open the innovation process for a new influx of ideas enabling co-creation.

#### 7.1.3.5 Organization

Concerning restructuring their organizations, most interview participants opted for a reorganization toward a shared service center. Only one interviewee stated that this is not planned for today or the near future.

[222] Junge et al. 2019, p. 44




L&SCM Logistics and supply chain management

**Figure 39:** (Re)-organization as shared service center (number of mentions)

The interviewees explained that the organization of L&SCM as a shared service center makes it easier to set up of interdisciplinary teams for dedicated projects. In part, back shoring of competences such as small parts logistics takes place as original equipment manufacturers realize that they need sovereignty over those processes to move closer to the aspired end-to-end optimization in their L&SCM networks.

One activity taking place to enable faster prototyping of projects, for example, within corporate L&SCM, is the creation of additional entities dedicated for DT in L&SCM. takes place. A challenge is to organize the interfaces to other entities such as IT and production sites well. Some participants' firms have also introduced swarm organizations in order to deal with such challenges. For more information about the current state of swarm organizations in L&SCM, please refer to Junge et al. (2019).[223]

[223] Cf. Junge et al. 2019, pp. 19f., p. 41


**Figure 40:** Swarm organization for logistics and supply chain management[224]

Overall, participants agreed that new skills profiles are needed within the new organizations. Human resource managers either develop competences internally or, more commonly, hire experts, for example, data scientists. Moreover, the implementation of DT technologies requires production planning and L&SCM to move closer together. This leads to a change that is reflected in the following quote from the interviews: *"Mindshift: the intelligence moves from production to logistics but therefore we need transparency and reliable data."*

As this section has shown, the interview participants are introducing projects to create more customer value in their L&SCM networks within the 3+1 values. It must be clearly stated that the predominant value appears to be that of availability, and there is still some insecurity about which services to develop further and how to monetarize them; but the awareness of, and aspirations to extend, L&SCM as a service are there. The value currently being least focused on is co-creation,

[224] Junge et al. 2019, p. 41

which is also reflected in the lack of status of the institutionalization of open innovation. However, organizations are adapting to meet the demand for more collaboration by setting up shared service centers.

The next section presents success factors for DT projects in L&SCM, as determined from the interviews.

#### 7.1.3.6 Success factors

The most significant finding for the stated success factors for DT projects in L&SCM is that the greatest emphasis lies on social factors.

**Social success factors**

These include talent and skills management, which can be organized, for example, by setting up an L&SCM talent management network. This can also help when developing new kinds of profiles needed for tasks in L&SCM. Qualification management might also shift; it is conceivable that in the future there will be one qualification profile belonging to the company and another, "individual," transferable profile belonging to each human. This will require security attributes for people and the assurance of the transferability of know-how and employees' profiles. This, in turn, can also create more trust and acceptance when data sovereignty for individuals is guaranteed.

For setting up and running DT projects, it is essential to include the people dimensions. Customers and employees need to be at the center, and companies should investigate how to acquire data to serve them in a better way. Change management is another important success factor. People must be brought along with the transformation. This requires creating a digital spirit and vision with board commitment.

As has been shown, the dependency among L&SCM network partners rises for realizing E2E projects, so trustful relationships among those partners become more important.

On an individual (management) level, interviewees identified high tolerance for frustration and high social competence for discussions as success factors.

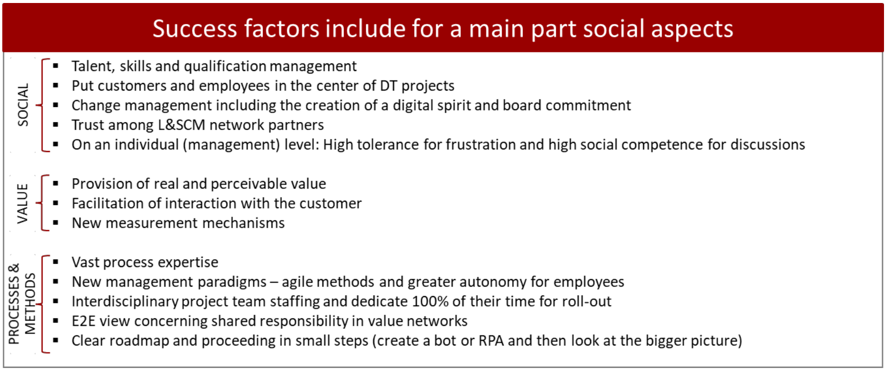
**Value related success factors**

For successful DT projects in L&SCM, it is decisive that they must create real value added. This is conceptualized in Chapter 6 and its forms are described in section 7.1.3.2. It is important to include how the customer perceives the value proposition, which might require new measurement mechanisms (refer to sections 6.1.3 and 7.1.3.3). One success factor is to prove the value with one or two partners and then captivate other partners with this value. This confirms the finding that the lead user method distinguishes best practice companies from others.[225] The guiding principle needs to be whether new solutions facilitate collaboration with the customer. Exemplary outcomes are reduced lead times, improvement of the cost base, or an L&SCM portfolio that is more attractive to the customer.

**Success factors relating to processes and methods (project management)**

Successful technology deployment requires vast process expertise. This necessitates interdisciplinary project team staffing and full dedication to the project, for example, allocating 100 % of project staff time for rollout. Further management success factors that the interviewees mentioned include agile methods and as giving greater autonomy to employees. For developing the scope of projects, it is important to apply an end-to-end view concerning shared responsibility in value networks, and for prioritizing and scheduling DT projects in L&SCM, having a clear roadmap and proceeding by small steps is essential. This means, for example, creating a bot or introducing robot process automation and then looking at the bigger picture.

[225] Cf. Junge et al. 2019, p. 33




| | |
|---|---|
| E2E | End-to-end |
| DT | Digital transformation |
| L&SCM | Logistics and supply chain management |
| RPA | Robot process automation |

**Figure 41:** Success factors for digital transformation projects

Master data availability and quality, as well as standards for data exchange, are prerequisites for successfully deployed solutions.

Questions that remains open in this area include whether to provide hardware or software solutions, or both, and concerning the resulting business model changes.

Nevertheless, interviewees stressed social aspects most, which is summarized by the following quote: *"Put humans in the focus. This is the linchpin."*

### 7.1.4 Summary and prospective change of the relationship to the customer

To summarize the findings from the interviews, it can be stated that consistent automation is not (yet) possible. Media discontinuities and different maturity levels between SC network partner still pose barriers (see also Figure 14). This results in the status that the security and validity required to make decisions autonomously is not yet available (transformation needs to be socially sustainable): *"The problem with prescriptive analytics is that the data base often does not contain sufficient data for a valid decision support."*

Despite the fact that (semi-)autonomous execution of operational tasks is still in its infancy – fully autonomous handling of the most important operational logistics functions is expected towards 2029[226] – advanced companies are clearly moving forward on their way to creating more customer value based on DT technologies. The focus is on increasing availability by improving transport and container management.

Relating to service, there is no clear trend yet regarding the areas in which services will offer the most value. Products sold as hybrid service bundles pose challenges concerning the different lifecycles of hardware and software, as well as accounting. Overall, the services deployed – for either internal or external customers – must provide dynamic instead of static planning and automate administrative tasks. Co-creating value focuses more on relationships with suppliers than with customers. Key points are the outsourcing of some tasks (e.g., quality control) within the concept of the extended workbench or co-creating assistance systems.

Applying open innovation concepts offers opportunities for developing L&SCM innovation capabilities, but to date is rarely institutionalized. Concerning organizational set-ups, a clear development towards L&SCM as a shared service center is observable.

When assessing success factors for L&SCM, the interviewees strongly focuses on the soft skills needed. The old paradigm – that an L&SCM network is only as strong as its weakest link – takes on a new meaning for DT, as technology dependency is increased across the network.

Future developments aim at providing end-to-end, real-time information for dynamic and reliable planning and steering. Furthermore, many operational activities will be reduced over the next 10–15 years, thus reducing headcount. The main

[226] Cf. Junge et al. 2019, p. 39

aim of DT projects is to reduce costs. Increasing the potential for sustainability is currently seen as a “by-product” of DT projects.

These developments raise the question of how they will change the relationship between L&SCM and the customer. When asked about the implications of the previously depicted developments, the interviewees do not indicate any unambiguous tendency.

On the one hand, there will be less face-to-face communication and less paper-based interaction, although current legislation still requires paperwork. On the other hand, communication has already changed and a lot of information is transmitted digitally (e.g., customs and mean transit times). The speed of communication and information availability has already increased, thus resulting in an increase in the demands and pressure on individuals. This, alongside more impersonal relationships, places new strains on humans as actors in those L&SCM networks. Technology dependency has also increased.

The interviewees offer partial support for the claim that the basics of the discussion and the relationship have not changed; DT requires trust on both sides, but the relationship has not significantly changed. The collaborative approach has, however, intensified. Another aspect is that digital information exchange has reduced manual labor and has increased flexibility and agility toward the customer.

Proponents of a consistent relationship to customers state that communication channels (electronic data interchange) stay the same and that the procedural collaboration has not changed. Examples identified are that customers have always requested advanced shipping notifications and communication is, to a great extent, standardized via electronic data interchange. The assumption is that the lack of personal interaction needs to be compensated for in order to sustain relationships.

The change towards suppliers has been more drastic concerning collaboration and interaction. However, a threat for customer relationships is that back-ups for DT-projects seldom exist.

The following section merges the findings from Chapters 5–7 into a conceptual architectural framework for DT in L&SCM.

## 7.2 Architectural framework for capturing and increasing customer value

The success of DT activities in L&SCM depends on a holistic and, if possible, end-to-end customer-centric approach. This implies that goals based on customer requirements must be stated and linked to sources of business value. Then the performance components and associated technologies to achieve that value need to be specified and implemented. The following paragraphs describe the scope of the framework, its aims, boundaries and foundations.

**What does the framework deliver?**

To describe the intentions of the framework, we will come back to the underlying definition of DT for this thesis (please refer to section 3.3):

| |
|---|
| Digital Transformation in Logistics and Supply Chain Management is the change in value creation enabled by existing and new technologies, adaptation of business strategies based on data-driven processes and services, and the creation of a supporting ecosystem. Its goal is to achieve increased flexibility, collaboration, efficiency and customer value, thereby ultimately leading to (semi-) autonomous execution of tasks and optimization in value networks. |

The framework describes how the change in value creation in L&SCM can be captured and what implications arise for value creation. As for the supporting ecosystems, it focuses on innovation and organizations as well as performance metrics. It gives advice for managers and has implications for further research that will be needed.

**What does is not deliver?**

The framework does not focus on the adaptation of business strategies and business models, as this is not within the scope of this thesis. However, the conclusion provides an outlook concerning business models.

Furthermore, the framework does not aspire to give a comprehensive overview of how to implement DT technologies in order to improve performance and increase customer value. However, based on the previous findings, it provides a) management recommendations, by presenting building blocks, tools and methods for how to address this topic; and b) scientific implications. The foundations on which it is based are laid out below.

**Theoretical foundation**

Chapter 2 describes the theoretical foundations. For the development of the framework, the task-technology fit[227] as well as the theory of mindful innovation[228] are important.

---

[227] Cf. Goodhue and Thompson 1995
[228] Cf. Swanson and Ramiller 2004

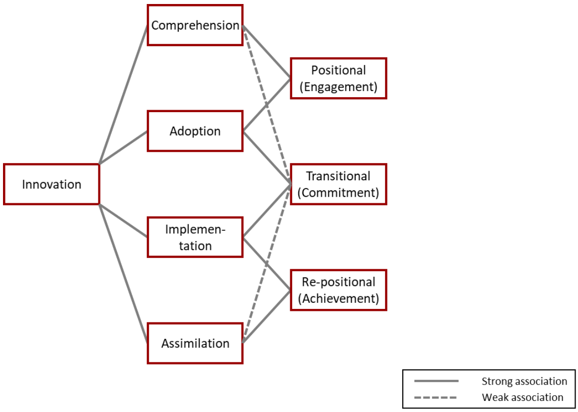



**Figure 42:** Mindful innovation[229]

The architecture model helps L&SCM planning executives. It offers assistance, although it is impossible to provide a fundamental architecture model that is applicable to all different kinds of businesses. Coherent with the focus of this thesis, the components of the framework are relevant to manufacturing industry with multi-variant series production.

229 Swanson and Ramiller 2004, p. 558

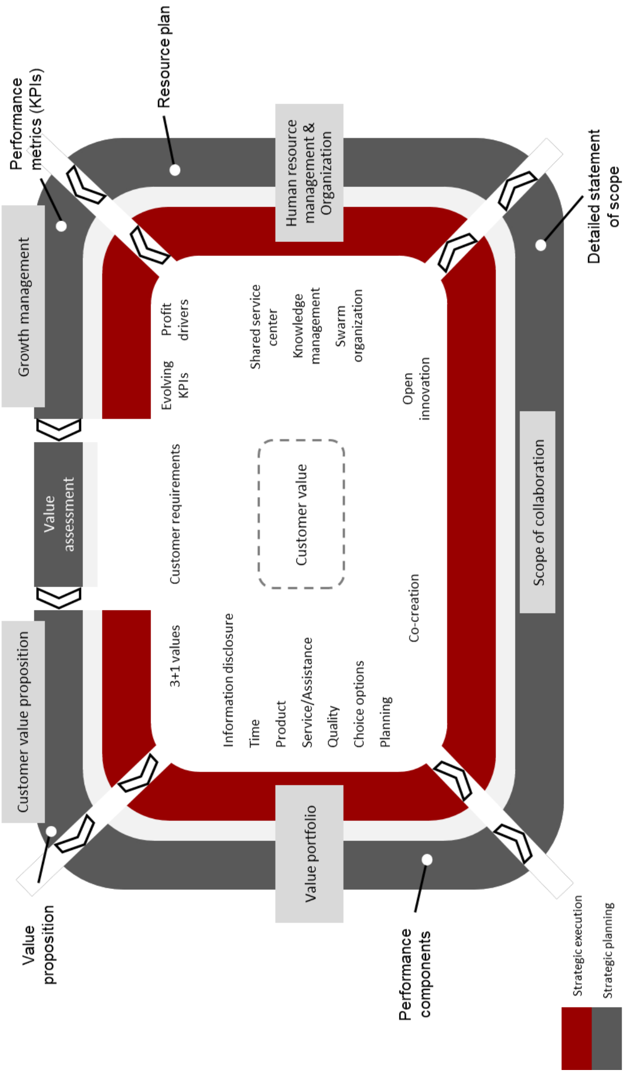



**Figure 43:** Architecture strategy for capturing and increasing customer value[230]

[230] Based on Ross 2011, p. 356

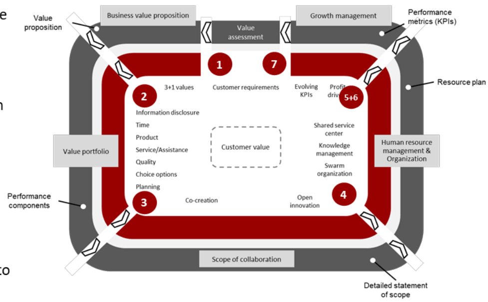
The proposed procedure for how to best implement DT technologies in L&SCM follows the classical approach of analyzing requirements and processes to conduct an As-Is – To-Be analysis (comprehension). To increase customer value, an L&SCM scenario is derived and its implications for innovation and the required resources and organization are laid out (adoption). The subsequent business case along with the piloting and testing of the solution prove the value before further rollout (implementation). Performance measurement and continuous adjustment assure (in theory) the sustenance of the competitive advantage. This results in the following seven steps:[231,232]

1. taking the customer's perspective
2. analyzing the processes and assessing value creation
3. L&SCM scenario based on DT technologies
4. L&SCM performance components and implications for innovation and organization
5. business case: Lead user (pilot and test product, service, and iteration)
6. implementation
7. assimilation: measure performance and continuously adjust to customer needs to sustain competitive advantage.

Figure 44 depicts the interrelation of the mindfulness theory, the proposed steps for implementing DT technologies, and the L&SCM DT technologies architecture model.

[231] Based on Swanson and Ramiller 2004, p. 558
[232] Based on Hofmann and Rüsch 2017, pp. 27 ff.

| Theory | Procedure | L&SCM DTT architecture model |
|---|---|---|
| Comprehension | 1. Taking the customer's perspective<br>2. Analyzing the processes and assess value creation | |
| Adoption | 3. L&SCM scenario based on DTT<br>4. L&SCM components and implications on innovation and organization | |
| Implementation | 5. Business case: Lead user (Pilot and test product, service + iteration)<br>6. Implementation | |
| Assimilation | 7. Assimilation: measure performance continuously adjust to customer needs to sustain the competitive advantage | |




| | |
|---|---|
| DTT | Digital Transformation Technologies |
| L&SCM | Logistics and Supply Chain Management |
| KPI | Key Performance Indicator |

**Figure 44:** Interrelation of theory, procedure and architecture strategy

The following paragraphs describe the six components of the L&SCM DT technologies architecture model. The building blocks, tools, and methods that rely on the findings have largely been presented previously. They are also enriched by the literature review.

### 7.2.1 Value assessment

For the values assessment, it is necessary to acquire a comprehensive understanding of various business aspects that are necessary to deliver value to clients. For L&SCM in particular, an end-to-end perspective is important. As became obvious during the interviews, assessments of customer requirements for L&SCM still follow quite traditional methods and are executed via traditional channels. As one of the success factors for DT is to be able to learn and adapt quickly to react to a changing business environment, changing customer needs and technological advancement, this is subject to change. Surveys show that 44 % of best practice companies pursuing DT projects use multiple sources of customer data to assess their (unmet) needs on a weekly basis.[233]

Bowersox (2005) proposes that, for a customer value assessment, preliminary considerations should include the answers to the following questions:[234]

- Are our core processes customer-centric?
- Is my firm willing to continuously "rewrite the rules" to meet the evolving needs of end consumers?
- Have we reviewed and established the value proposition concerning enterprise core processes?
- Are we willing to share strategic information, responsibilities, and resources with our L&SCM partners?
- Have we incorporated planning technology to synthesize common L&SCM requirements and determine tactics to meet consumer needs while maximizing asset utilization?
- Are we willing to integrate operationally with other firms, potentially even competitors, to facilitate enhanced SC responsiveness and performance?
- Does the DT vision fit our firm?

The answers to the questions provide a first indication of the openness of a company for DT projects and its preparedness, based on already deployed technology and the established processes.

The findings from the expert interviews have shown that advanced manufacturing companies see themselves as agile towards their customers and, for the most part, are open to sharing data if the incentives for both sides are clear.

Next, this thesis presents the classical process analysis, including an as-is versus to-be analysis, thus resulting in the customer value proposition.

[233] Cf. Bughin et al. 2019
[234] Cf. Bowersox et al. 2005, p. 29

### 7.2.2 Value proposition

As a guiding principle, the values based on DT technologies for L&SCM can be clustered into availability, servitization, co-creation, and cognition as enhancement (please refer to section 6.1.2).

Based on the assessed customer requirements, for example, desire for customization, the thesis will define the necessary area(s) of value creation (one of the proposed values or a combination), thus resulting in the creation of a value proposition.

The success factors derived from the expert interviews serve as guideline and assistance (cf. section 7.1.3.6). For the value creation part, they are intended to create a real and perceivable value, to facilitate the interaction with the customer and to introduce new measurement mechanisms. For further information regarding the measurement mechanisms, please refer to section 7.2.6.

In addition to the findings from the expert interviews, further avenues for deriving a customer value proposition are:

1. easing the customer service process (e.g., speed, quality)
2. optimization of the customer's experience: offer of personalized products and services, new touchpoints, more transparency about processes (e.g., process energy consumption, sustainability, marketing argument)
3. window to the customer: where are the control and interaction points along the L&SCM network in which customer information is needed, helpful and meaningful? How to identify those control points?
5. facilitation of L&SCM collaboration
6. digitally transformed distribution and delivery change the way products get to their customers (e.g., additive manufacturing).[235]

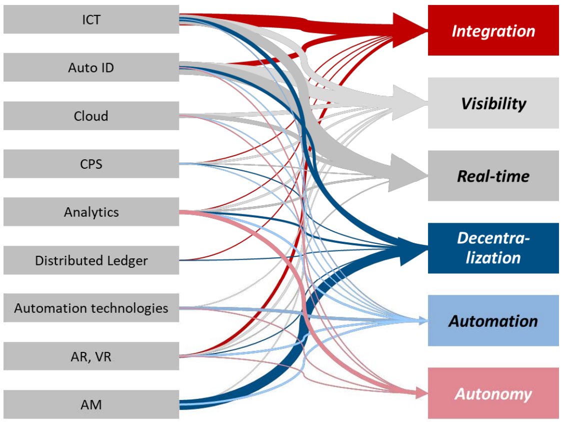
[235] Cf. Ross 2011, pp. 162 f.

Point 3, in particular, is closely related to value assessment and performance measurement within the L&SCM DT technologies architecture model.

The resulting value proposition determines the value portfolio and its inherent L&SCM performance components.

### 7.2.3 Value portfolio

The value portfolio based on DT technologies follows the structure of this thesis. Chapter 5 presents and describes the underlying DT technologies and their capabilities.




| | |
|---|---|
| ICT | Information and communication technology |
| ID | Identification |
| CPS | Cyber Physical System |
| AR/VR | Augmented Reality/Virtual Reality |
| AM | Additive Manufacturing |

**Figure 45:** Digital transformation technologies for logistics and supply chain management

Technology roadmaps can help to support DT in L&SCM. They should include:

1. a clear aim for how to improve the current situation based on DT technologies
2. the DT technologies needed to achieve that aim

3. a clear idea of who and which processes will be affected by the implementation of the respective DT technologies.[236]

For the impact assessment of the DT technologies, the reference frame, as presented in Chapter 4, offers guidance. As it is based on RAMI 4.0, it is explicitly apt for assessing production and ICT solutions and determining the area of influence of solutions that it organizations plan to deploy.

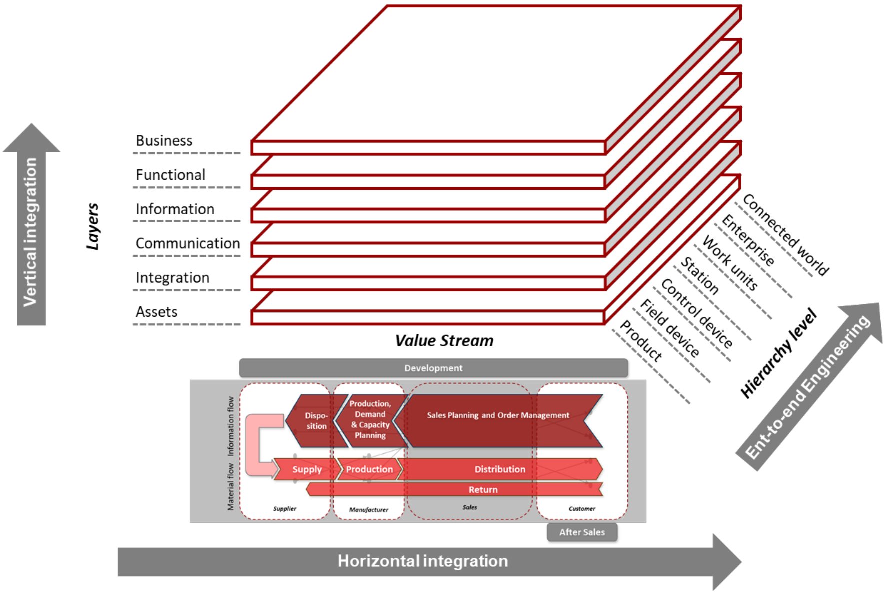



**Figure 46:** Reference frame for impact assessment of digital transformation technologies[237]

The performance components based on the respective DT technologies are described in chapter 6 evaluating that currently the creation of the value of availability is in focus and that the facilitation and support of planning activities play a superordinate role.

[236] Cf. McGirl 2018
[237] Cf. Adolphs et al. 2015, p. 7, based on Strandhagen et al. 2017, p. 345

The performance components deduced from the expert interviews show that currently there are clear foci for creating the 3+1 values in advanced manufacturing companies as shown in the following figure.

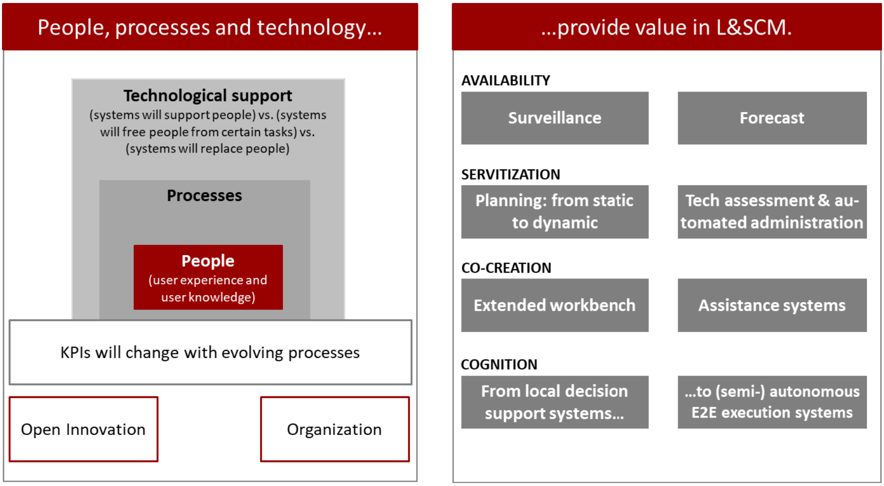



**Figure 47:** Foci of customer value creation in logistics and supply chain management

Appendix D provides a synthesis of value proposition components for L&SCM based on DT technologies.

### 7.2.4 Scope of collaboration

Surveys have shown that top companies most important leads concerning L&SCM are in the areas of customer collaboration.[238]

The interviews have shown that interest in further collaboration in terms of open innovation exists but that open innovation for L&SCM – in contrast to product development – is rarely institutionalized. For the implementation status of open

[238] Cf. Butner 2010, p. 19

innovation instruments such as innovation partnerships, innovation networks, innovation and technology marketplaces, innovation communities and idea contests, please refer to Junge et al. (2019).[239]

The best practice analysis shows that successful manufacturing companies apply the open innovation instruments of innovation communities and lead users.[240] The interviewees also mentioned the method of lead users to deploy solutions first in order to prove their value, to raise awareness and to generate credibility. In the case of a production network, the lead user would be a progressive production site open for implementing new solutions. This lead production site then provides an external perception that facilitates acceptance and further rollout at other sites.

The case of open innovation with end customers is quasi-non-existent for L&SCM. The first step is to gain insights about the product in use and then to generate a link to L&SCM processes. This is also valid for collaboration with suppliers (e.g., quality management).

A framework methodology for approaching such collaboration is as follows:

1. Experiment with novel innovation processes by collaborating continuously with customers or suppliers. Rewards as motivation for co-creation or the assurance of a mutual benefit need to be considered.
2. Open innovation approach: Integrate stakeholders who are otherwise traditionally separate in the innovation process to drive innovation – either internal or external stakeholders.
3. De-risk new product launch, assure a culture of failure tolerance.
4. Assure responsiveness to demand through continuous dialogue in multiple channels.
5. Enhance user experience and create a lasting customer relationship.[241]

[239] Cf. Junge et al. 2019, p. 27
[240] Cf. Junge et al. 2019, p. 33
[241] Cf. Zaki et al. 2017, p. 685

Consideration should also be given to linking entrepreneurial freedom for employees with open innovation instruments as entrepreneurial freedom is also a distinguishing concept of best practice manufacturing companies[242].

### 7.2.5 Organization and skills management

Based on the interviews, it can be stated that leading companies focus on setting up L&SCM as a shared service center to best serve their network during DT. Furthermore, facilitating the setup of interdisciplinary teams, for example, by enabling a swarm organization, is mentioned as a further implemented concept. An important success factor is that the assigned interdisciplinary teams can dedicate 100 % of their time to the rollout of new solutions.

The creation of DT technologies projects in L&SCM requires and relies on interdisciplinary teams posing new challenges for knowledge management. Schniederjans (2019) proposes a framework for knowledge management for DT in L&SCM.

[242] Cf. Junge et al. 2019, p. 33

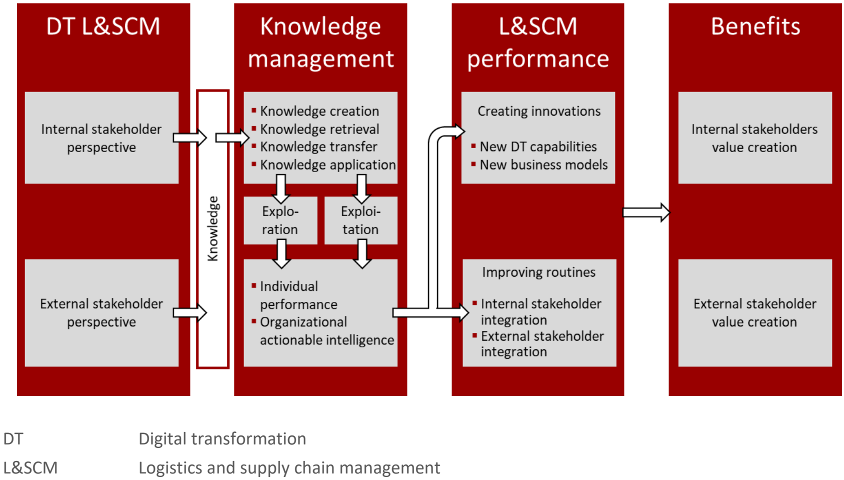



**Figure 48:** Knowledge management in logistics and supply chain management[243]

For further insights concerning knowledge management in the area of analytics in L&SCM, please refer to Herden (2019).[244]

Knowledge management also goes hand in hand with empowering people. Research shows that, for performance gains, knowledge management is indispensable to reinforce DT enablement's importance for employees at all levels. It improves the odds of DT projects being effective when people are assigned clear roles and responsibilities, for which people need the relevant capabilities. For interdisciplinary and cross-company teams working on DT projects, companies who foster a shared sense of accountability are more likely to report that the DT's objectives exceed expectations.[245]

This shared sense of accountability as well as the evolution of processes in L&SCM owing to the introduction of DT technologies suggest the evolution of performance metrics as the last component of the architecture framework.

[243] Cf. Schniederjans et al. 2019, p. 9
[244] Cf. Herden 2019
[245] Cf. Bughin et al. 2019

### 7.2.6 Performance metrics

Data governance for customer-centric L&SCM KPIs should, as a minimum, comprise every department that is in contact with customers, for example, sales, marketing, customer service, operations and L&SCM.

Based on the previous findings of this thesis, it is suggested that performance metrics (KPIs) in customer-oriented L&SCM might change in the following dimensions, based on DT technologies:

- evolving KPIs due to changing processes
- customer-related KPIs
- granularity of measurement
- scope of measurement.

The **evolvement of KPIs due to changing processes** was mentioned during the expert interviews. This mainly concerns the evolution from static to dynamic planning and execution. New KPIs might include the measurement of human–machine interaction, master data quality, and system availability. This will probably result in a) increasingly automatically captured KPIs and b) the disappearance of certain KPIs, such as on-time delivery.

Concerning **customer related KPIs**, companies first pursue attempts to relate data on the product in use to L&SCM. Once co-creation with customers in L&SCM increases, this will offer possibilities for generating more customer data and hence better understanding and meeting customer needs. However, if companies collect additional customer data, they will also be able to measure customer profitability in a more dedicated manner. If co-creation evolves towards more value adding activities lying with the customer (cf. Figure 49), this might also shift L&SCM KPIs.

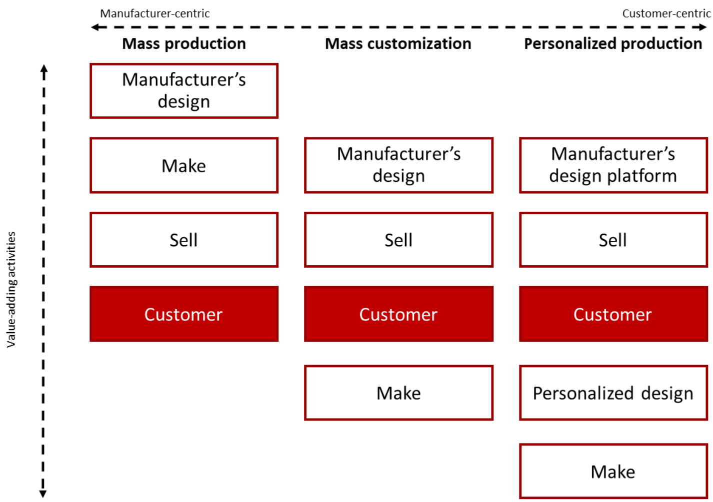



**Figure 49:** From a manufacturer-centric to a customer-centric logic[246]

Thanks to more granular data availability, the **granularity of measurement** mechanisms in L&SCM will also increase. This poses the question of how management will handle this granular data and measurement availability. As mentioned during the interviews, this might lead to systems only notifying in case of deviations (e.g., control towers), thus freeing managers from regularly checking KPIs.

Concerning the **scope of measurement** in L&SCM, end-to-end views concerning shared responsibility in L&SCM networks as well as the setting, that is, working in interdisciplinary teams across departments in companies, call for KPIs representing this shared accountability and setting appropriate incentives. In the current state, interviewees have not mentioned such an evolution of KPIs but the tendency that (technological) dependency and necessary trust among L&SCM network partners rises suggest that more holistic KPIs will evolve. Section 7.3 now describes the framework's validation.

[246] Bogers et al. 2016, p. 228

## 7.3 Validation

The validation consists of one expert interview. The interviewee is the managing director of an L&SCM consultancy focusing on transformation projects for large companies and has an academic background , including a dissertation about cyber-physical logistics systems. The interviewee has ten years of professional L&SCM experience.

The validation consists of two parts. First, the architectural framework is presented and discussed in order to clarify open questions. Then, the interviewee answered questions that cover the framework's six different building blocks (Appendix E). The interview was conducted face-to-face on January 30, 2020, and had a duration of 58 minutes. Subsequently, the interviewee assessed the presented hypothesis (refer to Appendix F), and this serves as an additional assessment of the outlook. This assessment is described in section 8.4.

The following pages present the results of the validation interview. They are described in the following manner: Each building block of the framework is presented, followed by a) implications for adapting the framework and/or b) implications for further research.

**Customer value proposition**

The interviewee confirmed the strong focus of the practitioners on the values of availability and servitization. Concerning co-creation, the suggestion is to increase the focus on make, buy or cooperate; however, this perspective is missing from his point of view.[247]

Concerning cognition, the interviewee currently does not see the strong focus on analytics leading to cognitive solutions in L&SCM. In reality, most companies focus on standardizing processes instead of thinking about autonomous, data-driven applications. This is, rather, on the horizon for 2030. A remark here is that

[247] For further elaboration, please refer to "scope of collaboration".

if you see DT as a preparation for more cognitive processes, then the value of cognition is appropriate.

Additional values are not proposed.

*Implications for framework adaptation*: none, since the values are confirmed and none additional is proposed.

*Implications for further research*: further research should include a focus on make, buy, or cooperate for co-creation value, which would belong to the framework component of "collaboration."

**Value portfolio**

The remark here is that the included performance components comprise various levels – from operational to strategic ones. In the interviewee's view, this is congruent with his experience of DT projects in L&SCM, where he observes that many approaches are very fragmented, thus leading to many stand-alone solutions.

The interviewee confirms agreement with the customer value propositions. He, however, suggests adding process analysis and standardization, as well as technology screening and selection, as additional components. The reasoning is that classical approaches rely on four levels, which are organization, processes, technology, and people. All four levels are guided by the company's strategic aims.

*Implications for framework adaptation*: minor. The remarks feed into the procedure linking theory and the framework. The technology screening and selection process and the process analysis are extensively discussed in the literature. Furthermore, the impact assessment model for DT on customer-based L&SCM offers guidance for L&SCM processes as well as the impacted hierarchy levels.

*Implications for further research*: -

**Scope of collaboration**

As already mentioned above, for co-creation and open innovation, the question of how to cooperate arises; this could be make, buy, or co-operate. Even though the focus of this thesis is on the co-creation process with L&SCM network stakeholders, cooperation is typically just the first step, then the innovating company is bought. A cultural fit between co-operation partners is often not present, which makes cooperation or open innovation very difficult.

Concerning the scope of collaboration, the findings have shown that open innovation is rarely institutionalized within L&SCM, which the interviewee confirmed.

Big companies, in his experience, build up their own labs or create decentralized entities. Fleetboard, which was incorporated in 2018, is one example; Rio is another. Labs aim to attract people and can draw on the companies' ecosystems.

In order to overcome existing barriers to applying more open innovation methods and approaches in L&SCM, the first question would be whether open innovation is necessary. If this is confirmed, there is a need to differentiate between logistics service providers and industry. Logistics service providers do not have money for innovation because of small margins. For industry, more positive and scalable examples are needed. Many solutions, including open-source, are already available. A Chief Digital Officer would be responsible for orchestrating open innovation. Innovation approaches for L&SCM now are increasingly in focus as L&SCM rises as an important topic for optimizations and receives more attention.

Open innovation can also create an additional business together with a venture entity. This is mainly a finance instrument (a question of insourcing and outsourcing). Venture entities can be good vehicles for innovations, leading to new business areas.

*Implications for framework adaptation:* -

*Implications for further research:* Research is needed on the identification and longitudinal study of the (successful) open innovation approaches of manufacturing companies for L&SCM, as well as their organizational anchoring and orchestration.

**Human resource management and organization**

For human resource management and organization, the interviewed experts stated that they offer agile ways of working, for example, independent expert teams. Furthermore, they work on finding new ways for knowledge management and reorganization of L&SCM as a shared service center. This approach was confirmed in the validation interview, but it was mentioned that a shared service center can also be termed a profit center, according to the interviewee.

From the interviewee's knowledge, successful approaches for best practice work and team organization for DT projects in L&SCM are based on the right mixture of competences. It is important to have people who are close to the customer and have vast process expertise; the technological perspective is important, followed by people in-between who have an interdisciplinary perspective. The challenge is to translate non-specific customer requirements into technological requirements. Often, people think in terms of already existing processes, identify optimization potential, and then think of the areas in which they can apply technologies. In contrast, technology personnel do not think in terms of processes. This is why you need a mediator. Scrum offers such a method. Establishing same-hierarchy levels and gender balance are additional best practices for such teams, considering that technology domains are mainly male dominated.

In the interviewee's view, key levers for knowledge management for L&SCM in times of DT are new digital tools for project management, for example, Jira or Confluence. A pitfall is that these tools are designed by technology people for technology people. For knowledge-management (e.g., based on the Information Technology Infrastructure Library (ITIL)), documentation is indispensable, and visualization is key. Many projects are not very transparent. Scrum and other methods are helpful, but often the different methods are not connected and compete with each other. Problems include a missing structure, such as a superordinate framework. This leads to rising frustration, because individuals do not know how their input leads to the overall solution.

*Implications for framework adaptation:* -

*Implications for further research:* Understand and describe the tools and methods for knowledge management, acknowledging to the variety of requirements of DT projects in L&SCM.

**Growth management**

The suggestion here is to rename “growth management” as “performance management,” as the focus of this building block is more on KPIS than on profit drivers, which would be new business models.

Concerning performance management and measurement, the experts interviewed previously stated that new KPIs will probably evolve but that they are unsure about their concrete form; this was confirmed during the validation interview.

In contrast to some of the earlier statements, the interviewee does not think that KPIs will evolve in a substantial manner because of DT. However, he observed that the number or priority of KPIs might change. An example could be that, for example, sustainability or time might be prioritized and the L&SCM network will subsequently adapt. For complexity reduction, KPIs might be aggregated and micromanagement could be done autonomously. Technological KPIs might be added, such as system stability or failures. Similar to the KPIs, expectations around assessing customer requirement might not change in the future, but will generally stay the same. The suspicion is that changes will be according to customer needs. Either the market will change, or the offer. No concrete change, however, is predictable yet.

*Implications for framework adaptation:* rename growth management as performance management.

*Implications for further research:* conceptualization of change concerning the assessment and measurement of customer requirements in L&SCM.

**Value assessment**

The value assessment was not part of the semi-structured interview guideline but, during the validation interview, it was mentioned that the match between customer requirements and the company’s strategic aims is very important. This requires answering the question of profitability and efficiency. Currently, this is not assessable because often it impossible to derive a valid business case. Innovation labs also cannot be seen as a business center per se. It is very hard to calculate a valid business case and to determine the return on investment for, for example, platform-based solutions, the main aims of which are qualitative in nature.

*Implications for framework adaptation:* -

*Implications for further research:* identification of suitable qualitative and quantitative value assessment methods and KPIs for DT in L&SCM.

## 7.4 Summary and adapted framework

Based on seven expert interviews, this thesis has developed a framework for capturing customer value based on DT technologies for L&SCM. The circuit framework comprises the customer value proposition, the value portfolio, the scope of collaboration, human resource management and organization, performance management, and the customer value assessment in order to readjust the proposed customer value. Based on the available data collected for this thesis (survey, literature review, NGT workshop, interviews), the constituent building blocks can now be described in more detail, thus providing suggestions for managers on how to approach DT in order to derive greater customer value from a L&SCM perspective. The framework was slightly adapted according to the findings from the validation interview. Although this confirmed the main parts, there are some changes based on the validation interview, and these are highlighted in red.

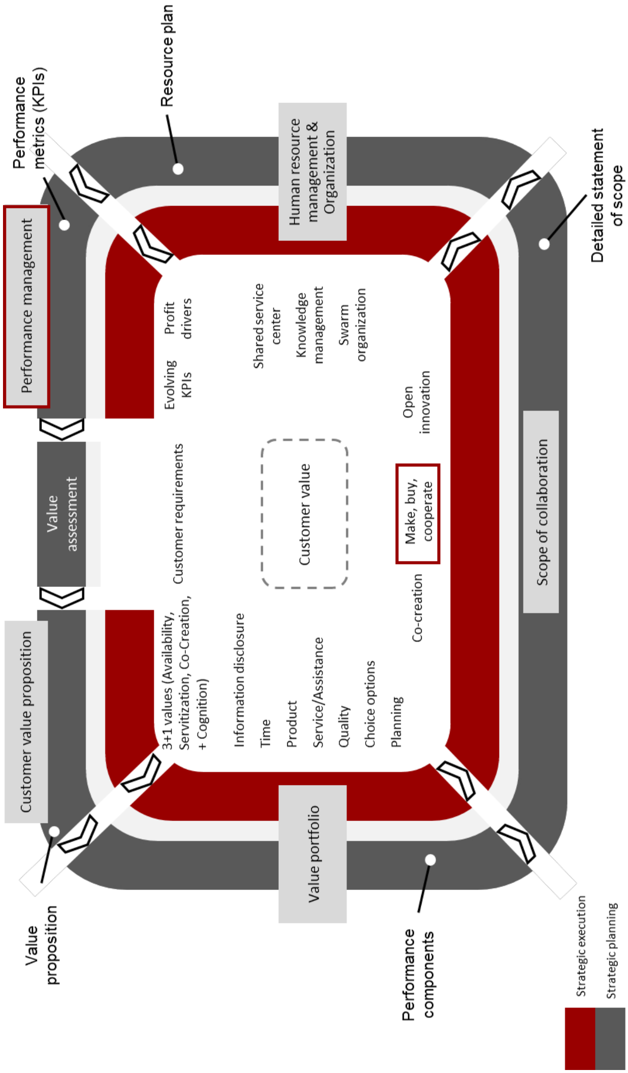



**Figure 50:** Validated and adapted architecture strategy for capturing customer value

# 8 Conclusion and outlook

The final chapter of this thesis is structured as follows: First, it provides a recapitulation of the research questions and findings, followed by the scientific as well as managerial contributions. The outlook and further research avenues plus the critical acknowledgment conclude the thesis.

## 8.1 Summary

The research questions of this thesis structure the summary. The primary research question is: *How can DT technologies contribute, and be mindfully used, to increase customer value in L&SCM?*

This primary research question is broken down into four secondary research questions.

a. *What is the status quo of DT in logistics systems in research and practice, especially in manufacturing industry? What are the main challenges to implementation?*

The data basis for answering the first secondary research question is a literature review and a survey among logistics experts. The analysis has shown that the impact of DT on L&SCM of manufacturing companies is still unclear. Summarizing the status quo allows the conclusion that manufacturing companies are building their technological portfolios to lay the basis for more advanced, (semi-) autonomous processes in L&SCM. Currently, the focus remains on creating visibility and integration of different L&SCM processes and network stakeholders. In this context, companies also need to rethink activities from product development through to delivery and after sales in order to focus on measures that are perceived as value enhancing for their customers. Barriers for DT projects in L&SCM are inconsistent data, lack of standards, and insufficient collaboration. These need to be overcome in order to move towards more autonomous processes in L&SCM.

The reference frame presented in section 4.4 offers guidance for creating ontologies and a common understanding for L&SCM partners. There is a consensus that technologies can help to overcome the challenges mentioned and can especially support fostering more customer-centric value creation networks.

b. *What are the relevant technologies for DT in manufacturing L&SCM systems and their respective capabilities?*

Based on an SLR, this thesis identified nine technology bundles as a foundation for DT in L&SCM. These are ICT, auto ID, cloud, CPS, analytics, distributed ledger, automation technologies, AR and VR, and additive manufacturing. They enable the capabilities of integration, visibility, real-time, decentralization, automation, and autonomy in L&SCM networks. Relating these to the stages of data capture, data analysis and extracting value from data, most approaches currently focus on the first two stages. In the future, this will enable value to be obtained from data in a meaningful way and with an end-to-end perspective, which relates to the capabilities of decentralization, automation and autonomy.

c. *How can DT technologies help increase customer value? How can these effects be conceptualized?*

Based on the literature, the thesis identified the three plus one values created by DT technologies in L&SCM. These are availability, servitization, co-creation, and cognition as enhancement. Additional performance dimensions for L&SCM are proposed, which are: information disclosure, time, quality, product, service, quality, choice options, and planning. Chapter six outlines a conceptualization of customer-based L&SCM performance based on DT technologies (refer to Figure 26). This conceptualization includes, alongside the customer-based performance dimensions and components, the performance context and the performance outcomes. As the thesis progressed, it excluded the performance context and outcomes and focused on the performance components.

A nominal group technique workshop with practitioners from manufacturing industry and logistics service providers revealed that DT technologies are used to create performance components within the industry clusters. These are: transparency based on data, software integration, transport, delivery and autonomous driving, automated material flow and picking, predictive maintenance, decentralized intelligence, customer interface/connection, and cross-sectional topics such as risk and compliance management. From the performance components proposed, a clear current prioritization can be deduced. The value of availability is more important than that of servitization, integration, or co-creation. Value of cognition is sometimes inherently captured but does not yet seem to be significantly in focus.

d. *What does an architectural framework for implementing DT technologies for capturing customer value in L&SCM look like? What are the resulting recommendations for logistics management?*

In order to gain insights about current and future performance components of advanced manufacturing companies, seven expert interviews provided data for constructing an architectural framework describing capturing customer value in L&SCM based on DT technologies. The framework provides building blocks for the customer value proposition, value portfolio, scope of collaboration, human resource management and organization, as well as performance management.

The subsequent validation showed that many of the building blocks of the framework are important and well based, but that including process management techniques as well as technology assessment methods would provide additional applicability.

## 8.2 Scientific contribution

The thesis' scientific contribution consists of four parts.

Firstly, it provides a definitional framing for DT in L&SCM, the underlying DT technologies and their capabilities.

Secondly, it offers a reference frame for customer-based performance for L&SCM in combination with DT technologies. Although the thesis focuses on performance components, the reference frame also includes the performance context and outcomes.

The third contribution builds upon the two preceding ones, and is the proposal of an architectural framework for increasing customer value in L&SCM based on DT technologies. Based on mindfulness theory, it offers guidance on how to structure the implementation of DT technologies in L&SCM.

The final scientific contribution lies in the advancement of performance measurement metrics in L&SCM, although here the advancement should be considered as an identified impulse, rather than as a finding.

## 8.3 Managerial contribution

L&SCM managers will mainly benefit from two aspects of this thesis.

The first is that the research can guide the implementation of DT technologies in L&SCM by proposing the reference frame for the impact assessment. This helps to identify and consider the relevant IT layers, hierarchy levels, and L&SCM areas that are impacted by the introduction of DT technologies.

Second, the architectural framework, by describing building blocks including performance components, provides a procedure for using DT technologies mindfully in L&SCM to increase customer value. The identified foci of the current state-of-the-art concern the values of availability, servitization, co-creation and cognition;

understanding these can help managers to compare their own current initiatives with those of leading manufacturing companies.

## 8.4 Outlook and further research

The hypothesis of this section is that L&SCM networks provide excellent performance for meeting customer needs once they are known.

In 2010, Butner stated:

> *It's the "knowing" part that is difficult. While other supply chains connect with customers primarily to provide timely, accurate delivery, smarter supply chains interact with customers throughout the product lifecycle – from research and development, to everyday usage, to product end-of-life. Pervasive instrumentation allows smarter supply chains to intercept demand signals at their source – items lifted from shelves, products leaving stores or critical parts showing signs of wear. In effect, every interaction becomes an opportunity for effortless customer collaboration. Smarter supply chains also use their intelligence to see beyond the masses. Through advanced analytics, they can identify ever-finer customer segments and tailor their offerings accordingly.*[248]

A decade later, in 2020, practitioners are working on this part – "knowing" customers. This will probably lead to a change in the KPIs measuring L&SCM performance. In L&SCM networks, end-to-end KPIs are needed in order to set incentives for holistic collaboration. This might also include the introduction of performance metrics for measuring customer value in relation to technology implementation. This will also lead to the research avenue of extending customer-based L&SCM performance to the resulting new business models, which would be the next logical step in pursuing this research.

[248] Cf. Butner 2010, p. 46

Concerning the proposed impact assessment reference frame, it would be desirable to extend it by introducing a substantial part concerning sustainability impacts. As of today, positive sustainability impacts of DT in L&SCM are seen as side effects. However, if society's awareness about resource sufficiency becomes prevalent, this might also imply extending the proposed 3+1 values with a value labelled "resource conservation."

Furthermore, subsequent research should also include the avenues of performance context and outcomes for further refining and understanding how customer value in L&SCM is shaped.

The architectural framework provides the first building blocks, but more research is needed to complement them, especially for the additional scope of collaboration (e.g., open innovation) and knowledge management. For open innovation, this can be the identification and longitudinal study of the (successful) open innovation approaches of manufacturing companies for L&SCM, as well as their organizational anchoring and orchestration.

**Hypotheses assessment**

The assessment of the hypotheses, as presented in Table 14, is an indication of the outlook provided by this thesis and not part of the validation. The same expert who answered the questions for the validation interview also evaluated the hypotheses. As the assessment shows, there is strong agreement concerning the shift of the focus toward the customer, which underpins the approach of this thesis. This will result in new interfaces and new interaction mediums. Increasing customer centricity will probably also imply that sales and operations planning will become even more demand driven and dependent on data availability. It remains uncertain whether this will result in new organizational control points becoming necessary to orchestrate L&SCM value networks. Possible avenues might be to reflect on which processes belong to a company's core competencies, feedback of interim status to customers, and autonomous quality gates. A shift in organizational settings will probably occur but it remains to be verified whether this implies that a shared service center is the best organizational structure for supporting DT in L&SCM. According to the assessment, increasing technological dependency will not lead to intensified collaboration based on open innovation approaches. Concerning network effects, a development towards more decentralized and smaller production sites is possible, but further research is required to determine the design of this and when it is likely to happen, as well its concrete L&SCM implications.

**Table 14:** Hypotheses assessment for outlook

| No. | Hypotheses | Agree | Rather agree | Unde-cided | Rather disa-gree | Dis-agree |
|---|---|---|---|---|---|---|
| 1 | In the future, L&SCM value assessment will focus more closely on **customer-related** interaction and KPIs. | x | | | | |
| 2 | New **customer interfaces for L&SCM** will evolve (e.g., mobile technology, shifting decoupling point, zero distance) | x | | | | |
| 3 | Different and **new customer interaction** in L&SCM will evolve (new forms of interaction, forward displacement of customer influence, open innovation). | x | | | | |
| 4 | For value creation in L&SCM, **new organizational control points are needed**. | | | x | | |
| 5 | **New organizational requirements are** needed concerning, e.g., knowledge management and distribution or organization of interdisciplinary teams (holocracy and heterarchy instead of hierarchy). | | x | | | |
| 6 | **Shared service centers** are the best organization for L&SCM supporting DT. | | | | x | |
| 7 | DT technologies lead to **an increase of work capability/ productivity per employee in L&SCM**. | | x | | | |
| 8 | **Increasing technological dependency** among L&SCM partners **will lead to more open innovation**. | | | | | x |
| 9 | **Higher resolution of information leads to new leadership requirements**. | | x | | | |
| 10 | DT technologies will lead to a shift to **more demand-driven sales and operations planning**. | x | | | | |
| 11 | DT technologies in L&SCM leads to **more decentralized** and **smaller** (e.g., micro factories) **production sites.** | | x | | | |

## 8.5 Critical acknowledgement

As is true for every research study, restrictions apply to the methodology and data basis of this study.

First, the results of the SLR are restricted by the sources used (Web of Science and EBSCO) and the language included (English). This leads to the fact that, for example, wearables and mobile technologies, sometimes mentioned as important technologies for DT, are not included among the DT technologies, because they were not part of the papers for the SLR. Nor were they mentioned during the nominal group technique or the expert interviews.

The framework development also neglects the viewpoint of logistics service providers, as they were not part of the interview panel.

Lastly, as already mentioned, the architectural framework building blocks are not exhaustive, but provide an insight about what successful manufacturing companies pursue in order to increase customer value in L&SCM based on DT technologies. The validation is based on one expert's opinion and should be extended by testing the framework in different environments. This should also include small and medium enterprises as the framework presented here rests only on data from large companies.

# 9 References

Accenture Strategy (2015): Mut, anders zu denken: Digitalisierungsstrategien der deutschen Top500. With assistance of Die Welt. Accenture Strategy; Die Welt. Available online at https://www.accenture.com/_acnmedia/Accenture/Conversion-Assets/DotCom/Documents/Local/de-de/PDF_3/Accenture-Deutschlands-Top500.pdf, checked on 10/11/2017.

Ackerman, Evan (2015): Chinese 'Unmanned Factory' Replaces 600 Humans With 60 Robots. Edited by IEEE Spectrum. Available online at https://spectrum.ieee.org/automaton/robotics/industrial-robots/chinese-unmanned-factory-replaces-humans-with-robots, checked on 6/20/2019.

Ackermann, Jörg; Börner, Frank; Hopf, Hendrik; Horbach, Sebastian; Müller, Egon (2013): Approaches for planning and operation of adaptable factories. In International Journal of Production Research 51 (15), pp. 4618–4629. DOI: 10.1080/00207543.2013.783243.

Adolphs, Peter; Bedenbender, Heinz; Dirzus, Dagmar; Ehlich, Martin; Epple, Ulrich; Hankel, Martin et al. (2015): Referenzarchitekturmodell Industrie 4.0 (RAMI4.0). Statusreport. Edited by VDI/VDE-Gesellschaft Mess- und Automatisierungstechnik, ZVEI.

Akinlar, Sevket (2014): Logistics 4.0 and challenges for the supply chain planning and IT. Edited by Fraunhofer IML. Istanbul.

Alsen, Daniel; Patel, Mark; Shangkuan, Jason (2017): The future of connectivity: Enabling the Internet of Things. Edited by McKinsey & Company. Available online at https://www.mckinsey.com/featured-insights/internet-of-things/our-insights/the-future-of-connectivity-enabling-the-internet-of-things, checked on 6/20/2019.

Anderl, Reiner; Bauer, Klaus; Diegner, Bernhard; Diemer, Johannes; Fay, Alexander; Goericke, Dietmar et al. (2016): Aspekte der Forschungsroadmap in den Anwendungsszenarien. Edited by Bundesministerium für Wirtschaft und Energie. Plattform Industrie 4.0. Berlin.

Appiah-Adu, Kwaku; Singh, Satyendra (1998): Customer orientation and performance: a study of SMEs. In Management Decision 36 (6), pp. 385–394. DOI: 10.1108/00251749810223592.

Aquifi (2019): Automation of Repetitive Visual Tasks For Manufacturing and Logistics. Available online at https://www.aquifi.com, checked on 6/20/2019.

Arica, Emrah; Powell, Daryl J. (2014): A framework for ICT-enabled real-time production planning and control. In Advances in Manufacturing 2 (2), pp. 158–164. DOI: 10.1007/s40436-014-0070-5.

Arntz, Melanie; Gregory, Terry; Zierahn, Ulrich (2018): Digitalisierung und die Zukunft der Arbeit: Makroökonomische Auswirkungen auf Beschäftigung, Arbeitslosigkeit und Löhne von morgen. Edited by ZEW Zentrum für Europäische Wirtschaftsforschung. Mannheim.

Bailey, George; Moss, Craig; Whittaker, Jim (2016): Digital Supply Chains: A Frontside Flip. Edited by The Center for Global Enterprise. Available online at http://thecge.net/category/research/digital-supply-chain-initiative/, checked on 1/7/2017.

Barney, Jay (2016): Firm Resources and Sustained Competitive Advantage. In Journal of Management 17 (1), pp. 99–120. DOI: 10.1177/014920639101700108.

Baumers, Martin; Duflou, Joost R.; Flanagan, William; Gutowski, Timothy G.; Kellens, Karel; Lifset, Reid (2017): Charting the Environmental Dimensions of Additive Manufacturing and 3D Printing. In Journal of Industrial Ecology 21 (S1), S9-S14. DOI: 10.1111/jiec.12668.

Bayat, Behzad; Bermejo-Alonso, Julita; Carbonera, Joel; Facchinetti, Tullio; Fiorini, Sandro; Goncalves, Paulo et al. (2016): Requirements for building an ontology for autonomous robots. In Industrial Robot 43 (5), pp. 469–480. DOI: 10.1108/IR-02-2016-0059.

Berman, Saul J. (2012): Digital transformation: opportunities to create new business models. In Strategy & Leadership 40 (2), pp. 16–24. DOI: 10.1108/10878571211209314.

Blackstone, John H. (2008): APICS dictionary. 12th ed. Athens, GA: APICS.

Blümel, Eberhard (2013): Global Challenges and Innovative Technologies Geared Toward New Markets. Prospects for Virtual and Augmented Reality. In Procedia Computer Science 25, pp. 4–13. DOI: 10.1016/j.procs.2013.11.002.

Bochmann, Lennart; Gehrke, Lars; Böckenkamp, Adrian; Weichert, Frank; Albersmann, Rainer; Prasse, Christian et al. (2015): Towards Decentralized Production: A Novel Method to Identify Flexibility Potentials in Production Sequences Based on Flexibility Graphs. In International Journal of Automation Technology 9 (3), pp. 270–282. DOI: 10.20965/ijat.2015.p0270.

Bogers, Marcel; Hadar, Ronen; Bilberg, Arne (2016): Additive manufacturing for consumer-centric business models. Implications for supply chains in consumer goods manufacturing. In Technological Forecasting and Social Change 102, pp. 225–239. DOI: 10.1016/j.techfore.2015.07.024.

Bogner, Eva; Voelklein, Thomas; Schroedel, Olaf; Franke, Joerg (2016): Study Based Analysis on the Current Digitalization Degree in the Manufacturing Industry in Germany. In Procedia CIRP 57, pp. 14–19. DOI: 10.1016/j.procir.2016.11.004.

Bowen, David E.; Siehl, Caren; Schneider, Benjamin (1989): A Framework for Analyzing Customer Service Orientations in Manufacturing. In The Academy of Management Review 14 (1), p. 75. DOI: 10.2307/258192.

Bowersox, Donald; Closs, David; Drayer, Ralph (2005): The Digital Transformation: Technology and Beyond. In Supply Chain Management Review (January/February 2005), pp. 22–29.

Bubner, Nedialka; Bubner, Nikolaus; Helbig, Ralf; Jeske, Martin (2014): Logistics Trend Radar. Delivering insight today. Creating value tomorrow!, pp. 1–52. Available online at http://www.detecon.com/sites/default/files/Logistics-TrendRadar_2014.pdf, checked on 3/2/2016.

Bughin, Jacques; Catlin, Tanguy; LaBerge, Laura (2019): A winning operating model for digital strategy. Available online at https://www.mckinsey.com/business-functions/mckinsey-digital/our-insights/a-winning-operating-model-for-digital-strategy?cid=other-eml-ttn-mip-mck&hlkid=f252ec1c343d475ca17858067c5946cb&hctky=10061307&hdpid=ae71699d-4fa5-4388-b718-381669804b9b#, checked on 1/9/2020.

Butner, Karen (2010): The smarter supply chain of the future. In Strategy & Leadership 38 (1), pp. 22–31. DOI: 10.1108/10878571011009859.

Cachon, Gérard P.; Fisher, Marshall (2000): Supply Chain Inventory Management and the Value of Shared Information. In Management Science 46 (8), pp. 1032–1048. DOI: 10.1287/mnsc.46.8.1032.12029.

Chae, Bongsug (2009): Developing key performance indicators for supply chain: an industry perspective. In Supply Chain Management: An International Journal 14 (6), pp. 422–428. DOI: 10.1108/13598540910995192.

Choi, T. Y.; Liker, J. K. (2002): Supply chain management as an emerging focus of technology management. In IEEE Transactions on Engineering Management 49 (3), pp. 198–204. DOI: 10.1109/TEM.2002.803383.

Christopher, Martin (2011): Logistics & supply chain management. 4. ed. Harlow: Financial Times Prentice Hall.

Christopher, Martin (2016): Logistics & supply chain management. Fifth Edition. Harlow, England, New York: Pearson Education.

Chung, Gina; Gesing, Ben; Chaturvedi; Bodenbrenner, Philipp (2018): Logistics Trend Radar. 2018/19. DHL Trend Research. Troisdorf.

Clegg, Chris W. (2000): Sociotechnical principles for system design. In Applied Ergonomics 31 (5), pp. 463–477. DOI: 10.1016/S0003-6870(00)00009-0.

Cooper, Martha C.; Ellram, Lisa M. (1993): Characteristics of Supply Chain Management and the Implications for Purchasing and Logistics Strategy. In The International Journal of Logistics Management 4 (2), pp. 13–24. DOI: 10.1108/09574099310804957.

Cucchiella, Federica; Gastaldi, Massimo (2006): Risk management in supply chain. A real option approach. In Journal of Manufacturing Technology Management 17 (6), pp. 700–720. DOI: 10.1108/17410380610678756.

Diemer, Johannes (2017): Sichere Industrie-4.0-Plattformen auf Basis von Community-Clouds. In Birgit Vogel-Heuser, Thomas Bauernhansl, Michael ten Hompel (Eds.): Handbuch Industrie 4.0. Bd. 1: Produktion. 2., erweiterte und bearbeitete Auflage. Berlin: Springer Vieweg (Springer Reference Technik), pp. 177–204.

Dighero, Craig; Kellso, James; Merizon, Debbie; Murphy-Hoye, Mary; Tyo, Richard (2005): RFID: The Real and Integrated Story. In Intel Technology Journal 9 (3), pp. 247–257.

Doch, Stefan Alexander (2015): Logistische Leistungsdifferenzierung im Supply Chain Management. Eds. Frank Straube, Helmut Baumgarten, Raimund Klinkner, Schriftenreihe Logistik der Technischen Universität Berlin 9.

Dong, Shutao; Xu, Sean Xin; Zhu, Kevin Xiaoguo (2009): Research Note —Information Technology in Supply Chains: The Value of IT-Enabled Resources Under Competition. In Information Systems Research 20 (1), pp. 18–32. DOI: 10.1287/isre.1080.0195.

Durach, Christian F.; Kurpjuweit, Stefan; Wagner, Stephan M. (2017): The impact of additive manufacturing on supply chains. In International Journal of Physical Distribution & Logistics Management 47 (10), pp. 954–971. DOI: 10.1108/IJPDLM-11-2016-0332.

Durão, Luiz Fernando; Christ, Alexander; Zancul, Eduardo; Anderl, Reiner; Schützer, Klaus (2017): Additive manufacturing scenarios for distributed production of spare parts. In The International Journal of Advanced Manufacturing Technology 93 (1-4), pp. 869–880. DOI: 10.1007/s00170-017-0555-z.

Dürrschmidt, Stephan (2001): Planung und Betrieb wandlungsfähiger Logistiksysteme in der variantenreichen Serienproduktion. H. Utz (Forschungsberichte IWB, Bd. 152), München.

DVZ (2018): Bosch und MAN gewinnen VDA Logistik Award 2018. Edited by Deutsche Verkehrs-Zeitung. Available online at https://www.dvz.de/rubriken/logistik/automobillogistik/detail/news/bosch-und-man-gewinnen-vda-logistik-award-2018.html, checked on 6/20/2019.

Esper; Terry L.; Peinkofer, Simone T. (2017): Consumer-Based Supply Chain Management Performance Research: A Structured Literature Review. In Transportation Journal 56 (4), pp. 395-428. DOI: 10.5325/transportationj.56.4.0395.

Eversheim, Walter (1989): Organisation in der Produktionstechnik Band 4. Fertigung und Montage. (VDI-Buch) 2nd ed. Berlin, Heidelberg: Springer Berlin Heidelberg.

Fleisch, Elgar; Weinberger, Markus; Wortman, Felix (2014): Business Models and the Internet of Things. Edited by Bosch IoT Lab White Paper. University of St. Gallen. Available online at http://cocoa.ethz.ch/downloads/2014/10/2090_EN_Bosch%20Lab%20White%20Paper%20GM%20im%20IOT%201_2.pdf, checked on 9/26/2017.

Fraunhofer ISI (2015): Industriebenchmarking Readiness I 4.0. Available online at http://www.industriebenchmarking.eu/readiness, checked on 9/26/2017.

Fugate, Brian S.; Mentzer, John T.; Stank, Theodore P. (2010): Logistics Performance: Efficiency, Effectiveness, and Differentiation. In Journal of Business Logistics 31 (1), pp. 43–62. DOI: 10.1002/j.2158-1592.2010.tb00127.x.

Gausemeier, Jürgen; Klocke, Fritz; Dülme, Christian; Eckelt, Daniel; Kabasci, Patrick; Kohlhuber, Martina et al. (2016): Industrie 4.0 - Internationaler Benchmark, Zukunftsoptionen und Handlungsempfehlungen für die Produktionsforschung. With assistance of acatech. Edited by Heinz Nixdorf Institut Universität Paderborn, WZL RWTH Aachen. Paderborn, Aachen. Available online at http://www.acatech.de/de/publikationen/publikationssuche/detail/artikel/industrie-40-internationaler-benchmark-zukunftsoptionen-und-handlungsempfehlungen-fuer-die-produ.html, checked on 6/30/2017.

Gezgin, Enis; Huang Xin; Samal, Prakashl; Silva, Ildefonso (2017): Digital transformation: Raising supply-chain performance to new levels. McKinsey & Company. Available online at https://www.mckinsey.com/business-functions/operations/our-insights/digital-transformation-raising-supply-chain-performance-to-new-levels?cid=other-eml-alt-mip-mck-oth-1712, checked on 7/29/2019.

Goodhue, Dale L.; Thompson, Ronald L. (1995): Task-Technology Fit and Individual Performance. In MIS Quarterly 19 (2), pp. 213–236.
DOI: 10.2307/249689.

Grosse-Ruyken, Pan Theo; Wagner, Stephan M.; Jönke, Ruben (2012): Manufacturing Performance: Der Status Quo bei deutschen Unternehmen. In Supply Chain Management I, pp. 13–18.

Grüninger, Michael; Shapiro, Steven; Fox, Mark S.; Weppner, Harald (2010): Combining RFID with ontologies to create smart objects. In International Journal of Production Research 48 (9), pp. 2633–2654. DOI: 10.1080/00207540903564975.

Hai, Rihan; Geisler, Sandra; Quix, Christoph (2016): Constance: An Intelligent Data Lake System. SIGMOD'16. Proceedings of the 2016 International Conference on Management of Data: June 26-July 1, 2016, San Francisco, California, USA. New York: Association for Computing Machinery, pp. 2097–2100. DOI: 10.1145/2882903.2899389

Heistermann, Frauke; Hompel, Michael ten; Mallée, Torsten (2017): Digitalisierung in der Logisitk. Antworten auf Fragen aus der Unternehmenspraxis. Bundesvereinigung Logistik. Bremen. Available online at https://www.bvl.de/misc/filePush.php?id=35017&name=BVL17+Positionspapier+Digitalisierung+in+der+Logistik, checked on 1/29/2020.

Herden, Tino T. (2019): Explaining the competitive advantage generated from Analytics with the knowledge-based view: the example of Logistics and Supply Chain Management. In Business Research 57 (5), p. 565. DOI: 10.1007/s40685-019-00104-x.

Hermann, Mario; Pentek, Tobias; Otto, Boris (2016): Design Principles for Industrie 4.0 Scenarios. In : 2016 49th Hawaii International Conference on System Sciences (HICSS). Koloa, HI, USA, 2016: IEEE, pp. 3928–3937.

Hess, Thomas; Matt, Christian; Benlian, Alexander; Wiesböck, Florian (2016): Options for Formulating a Digital Transformation Strategy. In MIS Quarterly Executive 15 (2), pp. 123–139.

Hilletofth, Per (2009): How to develop a differentiated supply chain strategy. In Industrial Management & Data Systems 109 (1), pp. 16–33. DOI: 10.1108/02635570910926573.

Hofmann, Erik; Knébel, Stephan (2013): Alignment of manufacturing strategies to customer requirements using analytical hierarchy process. In Production & Manufacturing Research 1 (1), pp. 19–43. DOI: 10.1080/21693277.2013.846835.

Hofmann, Erik; Knébel, Stephan (2016): Supply Chain Differentiation: Background, Concept and Examples. In Journal of Service Science and Management 09 (02), pp. 160–174. DOI: 10.4236/jssm.2016.92020.

Hofmann, Erik; Rüsch, Marco (2017): Industry 4.0 and the current status as well as future prospects on logistics. In Computers in Industry 89, pp. 23–34. DOI: 10.1016/j.compind.2017.04.002.

Holmqvist, Magnus; Stefansson, Gunnar (2006): 'Smart Goods' and mobile RFID A case innovation from Volvo. In Journal of Business Logistics 27 (2), pp. 251–272.

Holmström, Jan; Partanen, Jouni (2014): Digital manufacturing-driven transformations of service supply chains for complex products. In Supply Chain Management: An International Journal 19 (4), pp. 421–430. DOI: 10.1108/SCM-10-2013-0387.

Hormozi, Amir M. (2013): Means of Transportation in the Next Generation of Supply Chains. In SAM Advanced Management Journal, pp. 42–49.

Hunt, Shelby D.; Davis, Donna F. (2012): Grounding Supply Chain Management in Resource-Advantage Theory. In Defense of a Resource-Based View of the Firm. In Journal of Supply Chain Management 48 (2), pp. 14–20. DOI: 10.1111/j.1745-493X.2012.03266.x.

IBM Institute for Business Value (2010): The Smarter Supply Chain of the Future. Insights from the Global Chief Supply Chain Officer Study. IBM Corporation. Somers, NY, USA. Available online at https://www.ibm.com/services/us/gbs/bus/html/gbs-csco-study.html?cntxt%20%C2%BCa1005268, checked on 8/16/2019.

Innamorato, Tony; Prilepok, Milan; Schillinger, Ian (2017): The era of advanced analytics in procurement has begun. Edited by McKinsey & Company. Available online at https://www.mckinsey.com/business-functions/operations/our-insights/the-era-of-advanced-analytics-in-procurement-has-begun, checked on 6/18/2019.

JDA (Ed.) (2019): Luminate Demand Edge. Available online at https://jda.com/solutions/cognitive-saas-solutions/jda-luminate/luminate-demand-edge, checked on 6/18/2019.

Jelinek, Mariann (1977): Technology, Organizations, and Contingency. In The Academy of Management Review 2 (1), pp. 17–26. DOI: 10.2307/257601.

Jost, Jana; Kirks, Thomas; Mättig, Benedikt; Sinsel, Alexander; Trapp, Thies Uwe (2017): Der Mensch in der Industrie - Innovative Unterstützung durch Augmented Reality. In Birgit Vogel-Heuser, Thomas Bauernhansl, Michael ten Hompel (Eds.): Handbuch Industrie 4.0. Bd. 1: Produktion. 2., erweiterte und bearbeitete Auflage. Berlin: Springer Vieweg (Springer Reference Technik), pp. 153–173.

Junge, Anna Lisa (2020): Prospects of Digital Transformation Technologies (DTT) for Sustainable Logistics and Supply Chain Processes in Manufacturing. In Adriana Leiras, Carlos Alberto González-Calderón, Irineu de Brito Junior, Sebastián Villa, Hugo Tsugunobu Yoshida Yoshizaki (Eds.): Operations Management for Social Good. 2018 POMS International Conference in

Rio. Cham: Springer (Springer Proceedings in Business and Economics), pp. 713–720.

Junge, Anna Lisa; Verhoeven, Peter; Reipert, Jan; Mansfeld, Michael (2019): Pathway of Digital Transformation in Logistics. Edited by Frank Straube. Schriftenreihe Logistik der Technischen Universität Berlin, 8, Berlin.

Kagermann, Henning; Wahlster, Wolfgang; Helbig, Johannes (Eds.) (2013): Umsetzungsempfehlungen für das Zukunftsprojekt Industrie 4.0. Abschlussbericht des Arbeitskreises Industrie 4.0. acatech, Promotorengruppe Kommunikation der Forschungsunion Wirtschaft – Wissenschaft. Berlin.

Kersten, Wolfgang; Schröder, Meike; Indorf, Marius (2017a): Potenziale der Digitalisierung für das Supply Chain Risikomanagement: Eine empirische Analyse. In Mischa Seiter, Lars Grünert, Sebastian Berlin (Eds.): Betriebswirtschaftliche Aspekte von Industrie 4.0. Wiesbaden: Springer Fachmedien Wiesbaden (ZfbF-Sonderheft, 71/17), pp. 47–74.

Kersten, Wolfgang; Seiter, Mischa; See, Birgit von; Hackius, Niels; Maurer, Timo (2017b): Chancen der digitalen Transformation. Trends und Strategien in Logistik und Supply Chain Management. Hamburg: DVV Media Group GmbH.

Kille, Christian; Meißner, Markus (2016): „Gipfel der Logistikweisen“ – Eine Initiative zur Bewertung der quantitativen und qualitativen Entwicklung eines dynamischen Wirtschaftsbereichs für das kommende Jahr. In Christian Kille, Markus Meißner (Eds.): Logistik trifft Digitalisierung. Auswirkungen auf die Entwicklung in 2016. Hamburg: DVV Media Group GmbH, pp. 10–20.

Korpela, Kari; Hallikas, Jukka; Dahlberg, Tomi (2017): Digital supply chain Transformation toward Blockchain Integration. In: Hawaii International

Conference on System Sciences (HICSS-50), 2017. January 4-7, 2017, Waikoloa Village, Hawaii, pp. 4182–4191.

Kull, Thomas J.; Ellis, Scott C.; Narasimhan, Ram (2013): Reducing Behavioral Constraints to Supplier Integration. A Socio-Technical Systems Perspective. In Journal of Supply Chain Management 49 (1), pp. 64–86. DOI: 10.1111/jscm.12002.

Langley, C. John; Holcomb, Mary C. (1992): Creating Logistics Customer Value. In Journal of Business Logistics 13 (2), pp. 1–27.

Larson, Paul; Halldorsson, Arni (2004): Logistics versus supply chain management: An international survey. In International Journal of Logistics Research and Applications 7 (1), pp. 17–31. DOI: 10.1080/13675560310001619240.

Lee, Bill; Saunders, M. N. K. (2017): Conducting case study research for business and management students. 1st. Los Angeles: SAGE.

Lee, Haul (2004): The Triple-A Supply Chain. In Harvard Business Review 82 (10), pp. 102–112.

Lee, Jaegul; Berente, Nicholas (2012): Digital Innovation and the Division of Innovative Labor: Digital Controls in the Automotive Industry. In Organization Science 23 (5), pp. 1428–1447. DOI: 10.1287/orsc.1110.0707.

Liao, Hui; Subramony, Mahesh (2008): Employee customer orientation in manufacturing organizations: joint influences of customer proximity and the senior leadership team. In The Journal of applied psychology 93 (2), pp. 317–328. DOI: 10.1037/0021-9010.93.2.317.

Local Motors: A History of Making History. Available online at https://localmotors.com/heritage/, checked on 6/13/2019.

Marjanovic, Ugljesa; Lalic, Bojan; Delić, Milan; Tasic, Nemanja (2017): Industry 4.0: Evidence from Transitional Economy. In International Journal of Global Business, 10 (1), pp. 26–36.

Mayer, Horst O. (2013): Interview und schriftliche Befragung. Grundlagen und Methoden empirischer Sozialforschung. 6., überarb. Aufl. München: Oldenbourg.

Mayring, Phillipp (1991): Qualitative Inhaltsanalyse. In Uwe Flick (Ed.): Handbuch qualitative Sozialforschung. Grundlagen, Konzepte, Methoden und Anwendungen. München: Psychologie Verlags Union, pp. 209–213.

McGirl, Kevin (2018): Preparing the Supply Chain for Digital Transformation. Edited by Supply Chain Management Review. Available online at https://www.scmr.com/article/preparing_the_supply_chain_for_digital_transformation, checked on 1/12/2020.

Melnyk, Steven; Stanton, Daniel (2017): The customer-centric supply chain. In Supply Chain Management Review July/August 2017, pp. 8–17.

Mentzer, John T.; DeWitt, William; Keebler, James S.; Min, Soonhong; Nix, Nancy W.; Smith, Carlo D.; Zacharia, Zach G. (2001): Defining Supply Chain Management. In Journal of Business Logistics 22 (2), pp. 1–25. DOI: 10.1002/j.2158-1592.2001.tb00001.x.

Mentzer, John T.; Rutner, Stephen M.; Matsuno, Ken (1997): Application of the means-end value hierarchy model to understanding logistics service value. In International Journal of Physical Distribution & Logistics Management 27 (9/10), pp. 630–643. DOI: 10.1108/09600039710188693.

Meredith, Jack (1993): Theory Building through Conceptual Methods. In International Journal of Operations & Production Management 13 (5), pp. 3–11. DOI: 10.1108/01443579310028120.

Mittag, Peter (2019): Entwicklung eines anwendungsorientierten Gestaltungsansatzes zur Geschäftsmodellinnovation mithilfe von smarten Produkt-Service-Systemen. Eds. Frank Straube, Helmut Baumgarten, Raimund Klinkner. Schriftenreihe Logistik der Technischen Universität Berlin, Band 41, Berlin: Universitätsverlag der TU Berlin.

Morita, Michiya; Calvo, Jorge; Shirota, Yukari (2016): Envisioning SCM 4.0: The view from Japan. Edited by CSCMP (Supply Chain Quarterly, 03/2016). Available online at http://www.supplychainquarterly.com/topics/Manufacturing/20161021-envisioning-scm-40the-view-from-japan/, checked on 7/26/2017.

Moser, Daniel; Wecht, Christoph W.; Gassmann, Oliver (2016): Digitale Plattformen als Geschäftsmodell. In Oliver Gassmann, Philipp Sutter (Eds.): Digitale Transformation im Unternehmen gestalten. Geschäftsmodelle, Erfolgsfaktoren, Handlungsanweisungen, Fallstudien. München: Hanser, pp. 71–83.

Newman, Nic; Fletcher, Richard; Kalogeropoulos, Antonis; Levy, David; Kleis Nielsen, Rasmus: Reuters Institute Digital News Report 2017. Reuters Institute for the Study of Journalism.

Nyhuis, Peter; Mayer, Jonas; Kuprat, Thorben (2014): Die Bedeutung von Industrie 4.0 als Enabler für logistische Modelle. In Wolfgang Kersten, Hans Koller, Hermann Lödding (Eds.): Industrie 4.0. Wie intelligente Vernetzung und kognitive Systeme unsere Arbeit verändern. Berlin: Gito (Schriftenreihe der Hochschulgruppe für Arbeits- und Betriebsorganisation e.V. (HAB)), pp. 79–100.

Oonk, Maarten (Ed.) (2014): Smart logistics corridors and the benefits of Intelligent´Transport Systems. Transport Research Arena 2014. Paris, 2014-4-14 to 2014-4-17: Institut Francais des Sciences et Technologies des Transports, de l'Aménagement et des Reseaux (IFSTTAR) (Transport Research Arena (TRA) 2014 Proceedings). Available online at http://tra2014.traconference.eu/papers/pdfs/TRA2014_Fpaper_17861.pdf, checked on 3/9/2016.

Otto, Boris; Lohmann Steffen; Steinbuß, Sebastian; Teuscher, Andreas (2018): IDS Reference Architecture Model. Industrial Data Space. With assistance of Fraunhofer. International Data Spaces Association. Dortmund.

Prause, Martin; Weigand, Juergen (2016): Industry 4.0 and Object-Oriented Development: Incremental and Architectural Change. In Journal of Technology Management & Innovation 11 (2), pp. 104–110.

Rai, Arun; Patnayakuni, Ravi; Seth, Nainika (2006): Firm Performance Impacts of digitally enabled Supply Chain Integration Capabilities. In MIS Quarterly 30 (2), pp. 225–246.

Raut, Sandeep (2017): How do you measure the success of Digital Transformation? Data Science Central. Available online at https://www.datasciencecentral.com/profiles/blogs/how-do-you-measure-the-success-of-digital-transformation, checked on 8/16/2019.

Reipert, Jan (2019): Open Innovation in der Logistik – Entwicklung eines Gestaltungsmodells zum Aufbau eines offenen Innovationsmanagements in logistischen Dienstleistungsuntermnehmen. Eds. Frank Straube, Helmut Baumgarten, Raimund Klinkner. Schriftenreihe Logistik der Technischen Universität Berlin, Band 42, Berlin: Universitätsverlag der TU Berlin.

Ross, David Frederick (2011): Introduction to supply chain management technologies. 2. ed. Boca Raton, Fla.: CRC Press.

Roth, Lutz von (2016): Die Logistik wird smart Audi führt den selbststeuernden Anlieferprozess im Werk Ingolstadt ein. In Ingrid Göpfert (Ed.): Logistik der Zukunft - Logistics for the Future. Wiesbaden: Springer Fachmedien Wiesbaden, pp. 233–250.

Roy, Daniel Thomas (2017): Industrie 4.0 - Gestaltung cyber-physischer Logistiksysteme zur Unterstützung des Logistikmanagements in der Smart Factory. Eds. Frank Straube, Helmut Baumgarten, Raimund Klinkner. Schriftenreihe Logistik der Technischen Universität Berlin, Band 38, Berlin: Universitätsverlag der TU Berlin.

Sabet, Ehsan; Yazdani, Nahid; Leeuw, Sander de (2017): Supply chain integration strategies in fast evolving industries. In The International Journal of Logistics Management 28 (1), pp. 29–46. DOI: 10.1108/IJLM-01-2015-0013.

Salesforce (2018): State of the Connected Customer. Available online at https://www.salesforce.com/form/pdf/state-of-the-connected-customer-2nd-edition/?d=7010M000000uQVWQA2, checked on 6/13/2019.

Saunders, Mark; Lewis, Philip; Thornhill, Adrian (2016): Research methods for business students. 7. ed. Harlow: Pearson.

Savita, K. S.; Dominic, P.D.D.; Ramayah, T. (2016): The Drivers, Practices and Outcomes of Green Supply Chain Management. In International Journal of Information Systems and Supply Chain Management 9 (2), pp. 35–60. DOI: 10.4018/IJISSCM.2016040103.

Schenk, Michael (2015): Produktion und Logistik mit Zukunft. Springer Berlin Heidelberg.

Schleich, Benjamin; Anwer, Nabil; Mathieu, Luc; Wartzack, Sandro (2017): Shaping the digital twin for design and production engineering. In CIRP Annals 66 (1), pp. 141–144. DOI: 10.1016/j.cirp.2017.04.040.

Schmidt, Bernd; Rutkowsky, Sven; Petersen, Ingo; Klötzke, Felix; Wallenburg; Prof. Dr. Carl Marcus; Einmahl, Lucas (2015): Digital Supply Chains: Increasingly Critical for Competitive Edge. A.T. Kearney, Inc.; WHU Otto Beisheim School of Management.

Schniederjans, Dara G.; Curado, Carla; Khalajhedayati, Mehrnaz (2019): Supply chain digitisation trends: An integration of knowledge management. In International Journal of Production Economics, pp. 1-11. DOI: 10.1016/j.ijpe.2019.07.012.

Scholz, Peter (op. 2005): Softwareentwicklung eingebetteter Systeme. Grundlagen, Modellierung, Qualitätssicherung. Berlin: Springer.

Schrauf, Stefan; Berttram, Philipp (2016): Industry 4.0: How digitization makes the supply chain more efficient agile and customer-focused. Strategy&; PWC. Available online at https://www.strategyand.pwc.com/gx/en/insights/2016/digitization-more-efficient.html, checked on 1/29/2020.

Schuh, Günther; Anderl, Reiner; Gausemeier, Jürgen; Hompel, Michael ten; Wahlster, Wolfgang (2017): Industrie 4.0 Maturity Index. Managing the Digital Transformation of Companies. Edited by acatech. Munich.

Schuh, Günther; Jordan, Felix; Maasem, Christian; Zeller, Violett (2016): Industrie 4.0: Implikationen für produzierende Unternehmen. In Oliver Gassmann, Philipp Sutter (Eds.): Digitale Transformation im Unternehmen gestalten. Geschäftsmodelle, Erfolgsfaktoren, Handlungsanweisungen, Fallstudien. München: Hanser, pp. 39–58.

Seethamraju, Ravi (2008): Role of Enterprise Systems in Achieving Supply Chain Integration. In International Journal of Business Insights & Transformation 1 (2), pp. 1–7.

Seith, Christian (2018): Logistik im Werk Kecskemét. Komplexitätsbeherrschung durch das Warenkorbprinzip, 2018.

Setia, Pankaj; Venkatesh, Viswanath; Joglekar, Supreet (2013): Leveraging Digital Technologies: How Information Quality Leads to Localized Capabilities and Customer Service Performance. In MIS Quarterly 37 (2), pp. 565–590. DOI: 10.25300/MISQ/2013/37.2.11.

Siemens: Siemens Digital Logistics. Available online at https://www.siemens-digital-logistics.com/home-de.html, checked on 6/13/2019.

Sik Jeong, Jung; Hong, Paul (2007): Customer orientation and performance outcomes in supply chain management. In Journal of Enterprise Information Management 20 (5), pp. 578–594. DOI: 10.1108/17410390710823707.

Strandhagen, Jo Wessel; Alfnes, Erlend; Strandhagen, Jan Ola; Vallandingham, Logan Reed (2017): The fit of Industry 4.0 applications in manufacturing logistics. A multiple case study. In Advances in Manufacturing 5 (4), pp. 344–358. DOI: 10.1007/s40436-017-0200-y.

Straube, Frank (2004): e-Logistik. Ganzheitliches Logistikmanagement. Berlin: Springer-Verlag.

Straube, Frank (2017): Smarte Logistik: Hebel der Digitalisierung. Edited by Bundesvereinigung Logistik. Available online at https://www.bvl.de/service/zahlen-daten-fakten/logistikbereiche/smarte-logistik, checked on 6/12/2019.

Swanson, E. Burton; Ramiller, Neil C. (2004): Innovating Mindfully with Information Technology. In MIS Quarterly 28 (4), p. 553. DOI: 10.2307/25148655.

Tien, James M. (2012): The next industrial revolution. Integrated services and goods. In Journal of Systems Science and Systems Engineering 21 (3), pp. 257–296. DOI: 10.1007/s11518-012-5194-1.

Trist, E. L.; Bamforth, K. W. (1951): Some Social and Psychological Consequences of the Longwall Method of Coal-Getting. In Human Relations 4 (1), pp. 3–38. DOI: 10.1177/001872675100400101.

Uckelmann, Dieter (2008): A Definition Approach to Smart Logistics. In Sergey Balandin, Dmitri Moltchanov, Yevgeni Koucheryavy (Eds.): Next Generation Teletraffic and Wired/Wireless Advanced Networking, Vol. 5174. Springer Berlin Heidelberg (Lecture Notes in Computer Science), pp. 273–284.

van de Ven, A. H.; Delbecq, A. L. (1974): The Effectiveness of Nominal, Delphi, and Interacting Group Decision Making Processes. In Academy of Management Journal 17 (4), pp. 605–621. DOI: 10.2307/255641.

Voigt, Ingo (2018a): Automatisierung. Definition. Edited by Gabler Wirtschaftlexikon. Available online at https://wirtschaftslexikon.gabler.de/definition/automatisierung-27138, checked on 7/29/2019.

Voigt, Kai-Ingo (2018b): Serienproduktion. Edited by Gabler Wirtschaftlexikon. Springer Gabler. Available online at https://wirtschaftslexikon.gabler.de/definition/serienproduktion-43172/version-266504, checked on 2/15/2019.

Volkswagen AG (2019): Volkswagen mit neuer Software-Einheit. Wolfsburg. Available online at https://www.volkswagenag.com/de/news/2019/06/volkswagen-with-new-software-unit.html, updated on 6/18/2019, checked on 7/31/2019.

Wallace, Walter L.; Xia, Yusen (2015): Delivering customer value through procurement and strategic sourcing. A professional guide to creating a sustainable supply network / Walter L. Wallace, Yusen Xia. Upper Saddle River, New Jersey: Pearson Education (Financial Times operations management series).

Wang, Hongwei; Chen, Shuang; Xie, Yong (2010): An RFID-based digital warehouse management system in the tobacco industry: a case study. In International Journal of Production Research 48 (9), pp. 2513–2548. DOI: 10.1080/00207540903564918.

Wernerfelt, Birger (1984): A Resource-Based View of the Firm. In Strategic Management Journal 5 (2), pp. 171–180. Available online at http://www.jstor.org/stable/2486175.

World Economic Forum (2016): World Economic Forum White Paper Digital Transformation of Industries: Logistics Industry. With assistance of Accenture. World Economic Forum. Available online at http://reports.weforum.org/digital-transformation-of-industries/wp-content/blogs.dir/94/mp/files/pages/files/wef-dti-logisticswhitepaper-final-january-2016.pdf, checked on 5/13/2016.

Xiao, Yang; Yu, Senhua; Wu, Kui; Ni, Qiang; Janecek, Christopher; Nordstad, Julia (2007): Radio frequency identification: technologies, applications, and research issues. In Wireless Communications and Mobile Computing 7 (4), pp. 457–472. DOI: 10.1002/wcm.365.

Xue, Ling; Zhang, Cheng; Ling, Hong; Zhao, Xia (2013): Risk Mitigation in Supply Chain Digitization: System Modularity and Information Technology Governance. In Journal of Management Information Systems 30 (1), pp. 325–352. DOI: 10.2753/MIS0742-1222300110.

Yoo, Youngjin; Henfridsson, Ola; Lyytinen, Kalle (2010): Research Commentary —The New Organizing Logic of Digital Innovation. An Agenda for Information Systems Research. In Information Systems Research 21 (4), pp. 724–735. DOI: 10.1287/isre.1100.0322.

Zaki, Mohamed; Theodoulidis, Babis; Shapira, Philip; Neely, Andy; Surekli, Efe (2017): The Role of Big Data to Facilitate Redistributed Manufacturing Using a Co-creation Lens. Patterns from Consumer Goods. In Procedia CIRP 63, pp. 680–685. DOI: 10.1016/j.procir.2017.03.350.

Zanker, Klaus (2018): Branchenanalyse Logistik. Der Logistiksektor zwischen Globalisierung, Industrie 4.0 und Online-Handel. Düsseldorf: Hans-Böckler-Stiftung.

Zhang, Yingfeng; Liu, Sichao; Liu, Yang; Li, Rui (2016): Smart box-enabled product–service system for cloud logistics. In International Journal of Production Research 54 (22), pp. 6693–6706. DOI: 10.1080/00207543.2015.1134840.

Zhou, Guanghui; Xiao, Zhongdong; Jiang, Pingyu; Zhang, Yingfeng (2011): A radio frequency identification based optimal material delivery method for digital plant production. In International Journal of Computer Integrated Manufacturing 24 (5), pp. 493–505. DOI: 10.1080/0951192X.2011.554870.

Zigurs, Ilze; Buckland, Bonnie K. (1998): A Theory of Task/Technology Fit and Group Support Systems Effectiveness. In MIS Quarterly 22 (3), p. 313. DOI: 10.2307/249668.

Zillmann, Mario (2016): Keine Industrie 4.0 ohne Digitalisierung der Supply Chain. Intelligente Logistikdienstleistungen für die Fertigungsindustrie. With assistance of Lünendonk. Mindelheim.

# 10 Appendixes

## 10.1 Appendix A

Capabilities of digital transformation technologies (Chapter 5)

| Technology | Number of connections | Capability |
|---|---|---|
| ICT | 6 | Visibility |
| Auto ID (RFID) | 11 | |
| Cloud | 4 | |
| CPS | 2 | |
| Data analytics | 2 | |
| Distributed Ledger | 0 | |
| Automation | 1 | |
| AR, VR | 2 | |
| Additive manufacturing | 1 | |
| ICT (ERP etc.) | 11 | Integration |
| Auto ID (RFID) | 5 | |
| Cloud | 0 | |
| CPS | 1 | |
| Data analytics | 1 | |
| Distributed Ledger | 1 | |
| Automation | 0 | |
| AR, VR | 3 | |
| Additive manufacturing | 0 | |
| ICT (ERP etc.) | 9 | Real-time |
| Auto ID (RFID) | 12 | |
| Cloud | 4 | |
| CPS | 1 | |
| Data analytics | 2 | |
| Distributed Ledger | 0 | |
| Automation | 0 | |
| AR, VR | 1 | |
| Additive manufacturing | 0 | |
| ICT (ERP etc.) | 4 | Decentralization |
| Auto ID (RFID) | 3 | |
| Cloud | 0 | |
| CPS | 1 | |
| Data analytics | 2 | |
| Distributed Ledger | 1 | |
| Automation | 0 | |
| AR, VR | 1 | |
| Additive manufacturing | 9 | |
| ICT (ERP etc.) | 1 | Automation |

| | | |
|---|---|---|
| Auto ID (RFID) | 1 | |
| Cloud | 1 | |
| CPS | 1 | |
| Data analytics | 2 | |
| Distributed Ledger | 0 | |
| Automation | 3 | |
| AR, VR | 2 | |
| AM | 2 | |
| ICT (ERP etc.) | 0 | Autonomy, Cognition |
| Auto ID (RFID) | 1 | |
| Cloud | 1 | |
| CPS | 0 | |
| Data analytics | 4 | |
| Distributed Ledger | 0 | |
| Automation | 1 | |
| AR, VR | 1 | |
| Additive manufacturing | 0 | |

## 10.2 Appendix B

Data Nominal Group Technique Workshop (Chapter 6)

Template

**What are the Logistics and SCM strategies based on the presented technologies that increase customer value?**

☐ LSP
☐ Industry

| Strategy/measure to increase customer value | Technologies | Time Horizon | Importance for your company's strategic goals | Comments |
|---|---|---|---|---|
| | ☐ ICT ☐ Automation<br>☐ Auto ID ☐ AR, VR<br>☐ CPS ☐ AM<br>☐ Analytics ☐ Other:<br>☐ Blockchain ________ | ☐ Today<br>☐ 1-3 years<br>☐ 3-5 years<br>☐ 5-10 years<br>☐ Later | ☐ High priority<br>☐<br>☐ Medium priority<br>☐<br>☐ Low priority | |
| | ☐ ICT ☐ Automation<br>☐ Auto ID ☐ AR, VR<br>☐ CPS ☐ AM<br>☐ Analytics ☐ Other:<br>☐ Blockchain ________ | ☐ Today<br>☐ 1-3 years<br>☐ 3-5 years<br>☐ 5-10 years<br>☐ Later | ☐ High priority<br>☐<br>☐ Medium priority<br>☐<br>☐ Low priority | |
| | ☐ ICT ☐ Automation<br>☐ Auto ID ☐ AR, VR<br>☐ CPS ☐ AM<br>☐ Analytics ☐ Other:<br>☐ Blockchain ________ | ☐ Today<br>☐ 1-3 years<br>☐ 3-5 years<br>☐ 5-10 years<br>☐ Later | ☐ High priority<br>☐<br>☐ Medium priority<br>☐<br>☐ Low priority | |

ICT= Information & Communication Technologies
ID=Identification
CPS= Cyber Physical Systems
AR/VR= Augmented/Virtual Reality
AM= Additive Manufacturing

## 10.3 Appendix C

Semi-structured interview guideline (Chapter 7.1)

| | |
|---|---|
| **0. General information** | 1. Industry, turnover, number of employees, position, years of L&SCM experience, describe the customer you serve (B2B, B2C). |
| **I. Strategy for DT in L&SCM** | 2. How would you rate your DT-maturity in L&SCM?<br>3. Do you have a strategy for DT in L&SCM? If yes, when did it start? Do you have an accompanying vision for 2030? Who is organizationally responsible?<br>4. Is your firm willing to continuously "rewrite the rules" to meet the evolving needs of end consumers?<br>5. Are you willing to share strategic information, responsibilities, and resources with our supply chain partners?<br>6. Are you willing to integrate operationally with other firms, potentially even competitors, to facilitate L&SCM responsiveness and performance? |
| **II. Customer value enhancing strategies** | 7. Taking the customer perspective: How are customer expectations assessed? What are resulting implications?<br>8. Value of availability<br>9. Value of servitization<br>10. Value of co-creation<br>11. Value of cognition<br>12. Do you measure performance of newly deployed L&SCM performance components? If yes, how?<br>13. Has your relationship to and interaction with customers changed since DT projects have started? If yes, how?<br>14. How are open innovation strategies integrated and what are control points you need to maintain in order to sustain your competitive advantage?<br>15. Has the organizational structure for logistics and SCM changed due to DT? E.g. towards a shared service center but also concerning the connection of interdisciplinary teams? |
| **III. Resulting recommendations** | 16. Derived recommendations/success factors for<br>a) deploying the solutions (describe approach)<br>b) sustaining the advantage (control points) |

## 10.4 Appendix D

Synthesis of value proposition components for L&SCM based on digital transformation technologies (Chapter 7.2)

| | | Customer Value Creation Strategy | | | |
|---|---|---|---|---|---|
| **Performance components dimensions** | **Performance components** | **Availa-bility** | **Serviti-zation** | **Co-crea-tion** | **Cognition** |
| Information dis-closure | Forecast improvement towards 2nd tier supplier | x | | | |
| | E2E surveillance about material flows between production facilities | x | (x) | | |
| | Track and trace with focus on inbound logistics | x | (x) | | |
| | Container management with smart containers (saves empty container invento-ries & yearly inventory checks at suppliers) | x | x | | |
| Time | Trunk delivery for field service (operational since a decade but now supported by better forecasts) | | x | x | |
| Product/ Produc-tion | Building of a digital twin of the own production | x | (x) | | |
| | Connectivity and integration of AGVs | | | | x |
| | Customers provide data about product usage which in return is used to improve SC processes (e.g. capture movement profiles) | | | x | |
| | Extended workbench: e.g. additive manufacturing at the customer without shipping the part | x | x | x | |
| | Behavioral aspects of the product in use are related to production line and maintenance intervals with machine learning | (x) | (x) | (x) | x |
| Service | Reduction of empty trucks | (x) | x | | |
| | Standardized WMS for improving availability & reducing inventory | (x) | x | | |
| | Dynamical warehousing strategy | (x) | x | | |
| | Digital transport file -> based on this, different services will be offered: dynamic delivery windows for trucks, automated invoicing, paperless transport. | (x) | x | | |
| | Digitalization of customs paper | (x) | x | | |
| | Route optimization (e.g. determination of hubs) | | | | x |
| | Internally developed TMS and track & trace solutions | x | x | | |
| | New services based on data lakes (e.g. spare parts management for customers) | (x) | x | | |
| | Assistance systems for the production sites (e.g. critical path analysis, estimated supply range) | | x | | |

| | | | | | |
|---|---|---|---|---|---|
| | Dynamical steering of inbound delivery with trucks (internally developed EDI message solution to give recommendations) | | x | | |
| | Automated invoicing | | x | | |
| | Technology assessment: component recognition | | x | | |
| | Control tower for disposition reorganization | x | x | | |
| | Carrying out inventory by drones equipped with camera systems | (x) | x | | |
| | Integration of information from forwarders' TMS to receive processed ETA and to offer them the dynamic ramp-up planning and steering | x | x | x | |
| | Dynamical planning of employee staffing and planning of sequences | (x) | x | | |
| | Ambiguous assistance systems for production sites | | x | (x) | |
| | Bots for simple tasks | | x | | x |
| Quality | Digital quality management at the supplier | x | | | |
| | Joint development of warehouses with suppliers | | | x | |
| Choice options | - | | | | |
| Planning | Better planning and forecasting for e.g. raw material | x | | | |
| | Internal planning tool to increase planning quality and flexibility by real-time data about availability | x | | | |
| | Internal planning tool for production autonomously<br>determines alternative solution paths | | (x) | | x |
| | Link internal production planning and forecasting tools to other SC partner (e.g. Tier 1) | x | (x) | | x |
| | Prescriptive demand management | x | x | | x |

x = Primary focus (x) = Additional focus

## 10.5 Appendix E

Guideline Validation Interview (Chapter 7.4)

Position interviewee:

Experience L&SCM (in years):

**Validation of the architectural framework**

| | |
|---|---|
| DT | Digital Transformation |
| L&SCM | Logistics & Supply Chain Management |

**Questions for semi-structured interview**:

1. The proposed framework intends to present building blocks for a L&SCM DT technologies architecture strategy for capturing and increasing customer value. The building blocks are value assessment, customer value proposition, value portfolio, scope of collaboration, human resource management and organization, and growth management.
    a. In your opinion and considering the definition for DT in L&SCM for this thesis, do the constitutional building blocks make sense?
    b. Do you see additional building blocks that might be worth integrating in the architectural framework?
2. The framework is built on the assumption, that the value proposition based on digital transformation technologies in L&SCM consists of 3+1 values (availability, servitization, co-creation and cognition as enhancement).
    a. Do you consider the proposed values being exhaustive?
    b. If you see additional values, what values do come to your mind?

3. The proposed value portfolio based on the data collection for this thesis presents 35 performance components in seven dimensions (please refer to Appendix D).

    a. From your experience, do you agree with the proposed dimensions?

    b. Do you see additional performance components that your clients currently focus on within their DT technologies project in L&SCM?

4. Concerning the scope of collaboration, the findings have shown, that open innovation is rarely institutionalized within L&SCM.

    a. Can you confirm the statement?

    b. Can you name successful methods and approaches for open innovation in L&SCM form manufacturing companies?

    c. What do you think needs to be overcome in order to apply more open innovation methods and approaches in L&SCM?

5. For human resource management and organization, the interviewed experts state that they offer more agile ways of working (independent expert teams), work on finding new ways for knowledge management and reorganize L&SCM as a shared service center.

    a. Can you confirm the trend towards organizing L&SCM as a shared service center?

    b. From your knowledge, what are successful approaches for best practice work and team organization for DT projects in L&SCM?

    c. What do you think are key levers for knowledge management for L&SCM in times of DT?

6. Concerning performance management and measurement experts stated that probably new KPIs will evolve but that they are unsure about their concrete form.

   a. Do you agree with this assessment based on your experience?

   b. In what areas do you think new KPIs will evolve? Will others vanish? What might be examples of future KPIs?

   c. Do you think new measurement mechanisms to assess customer requirements will be applied in the future? If yes, can you name examples?

7. Do you have additional remarks in order to give feedback to the proposed framework?

## 10.6 Appendix F

Hypotheses outlook (Chapter 8.4)

| No. | Hypotheses | Agree | Rather agree | Unde-cided | Rather disagree | Disagree |
|---|---|---|---|---|---|---|
| 1 | In the future L&SCM value assessment will focus more closely on **customer related** interaction and KPIs. | | | | | |
| 2 | New **customer interfaces for L&SCM** will evolve (e.g. mobile technology, shifting decoupling point, zero distance) | | | | | |
| 3 | Different and **new customer interaction** in L&SCM will evolve (new forms of interaction, forward displacement of customer influence, open innovation) | | | | | |
| 4 | For value creation in L&SCM **new organizational control points are needed**. | | | | | |
| 5 | **New organizational requirements are** needed concerning e.g. knowledge management and distribution or organization of interdisciplinary teams (holocracy and heterarchy instead of hierarchy). | | | | | |
| 6 | **Shared service centers** are the organization for L&SCM best supporting DT. | | | | | |
| 7 | DT technologies lead to **an increase of work capability/ productivity per employee in L&SCM**. | | | | | |
| 8 | **Increasing technological dependency** among L&SCM partners **will lead to more open innovation**. | | | | | |
| 9 | **Higher resolution of information leads to new leadership requirements**. | | | | | |
| 10 | DT technologies will lead to a shift to **more demand-driven sales and operations planning**. | | | | | |
| 11 | DT technologies in L&SCM leads to **more decentralized** and **smaller** (e.g. micro factories) **production sites.** | | | | | |

**Schriftenreihe Logistik der Technischen Universität Berlin**
Hrsg.: Frank Straube, Raimund Klinkner, Helmut Baumgarten

ISSN 1865-3170 (print)
ISSN 2197-0564 (online)

---

**01: Mayer, Axel: Modularisierung der Logistik**. Ein Gestaltungsmodell zum Management von Komplexität in der industriellen Logistik. - 2007. - XVIII, 264 S., zahlr. Abb.
ISBN **978-3-7983-2054-3** vergriffen

**02: Thom, Alexander: Entwicklung eines Gestaltungsmodells zum Management von Risiken in Produktionsnetzwerken**. Ein Beitrag zum Risikomanagement in der Logistik. - 2008. - XX, 239 S., zahlr. Abb.
ISBN **978-3-7983-2975-8** EUR **5,00**

**03: Bogatu, Christian: Smartcontainer als Antwort auf logistische und sicherheitsrelevante Herausforderungen in der Lieferkette**. Auswirkungen und Handlungs-empfehlungen für die Wertschöpfungskette der Logistik. - 2008. - XXIV, 286 S., zahlr. Abb.
ISBN **978-3-7983-2074-1** EUR **5,00**

**04: Beckmann, Thomas: Emerging Market Sourcing.** Eine empirische Untersuchung zu Erfolgsfaktoren in der Beschaffung aus Wachstumsmärkten. - 2008. -XI, 221 S.
ISBN **978-3-7983-2096-3** EUR **5,00**

**05: Dietman, Nils von: Airport Performance Measurement.** Kennzahlensystem zur Analyse und Bewertung von Flughafenprozessen. - 2008. - XXI, 204 S., zahlr. Abb. u. Tab.
ISBN **978-3-7983-2103-8** EUR **5,00**

**06: Hildebrand, Wolf-Christian: Management von Transportnetzwerken im containerisierten Seehafenhinterlandverkehr**. - 2008. - XVI, 234 S., zahlr. Abb.
ISBN **978-3-7983-2102-1** EUR **5,00**

**07: Wilmking, Niklas: Logistikmanagement in China.** Eine empirische Untersuchung zur Strategieentwicklung von Logistikdienstleistern. - 2009. - VIII, 247 S., zahlr. Abb.
ISBN **978-3-7983-2130-4** EUR **5,00**

**08: Vogeler, Stefan: Entwicklung eines Vorgehensmodells zur Implementierung der RFID-Technologie in logistischen Systemen am Beispiel der Bekleidungswirtschaft**. - 2009. - XI, 227 S., zahlr. Abb.
ISBN **978-3-7983-2156-4** EUR **5,00**

**09: Doch, Stefan Alexander: Logistische Leistungsdifferenzierung im Supply Chain Management.** Theoretische und empirische Entwicklung eines Gestaltungsansatzes für die Differenzierung der logistischen Leistungserstellung produzierender Unternehmen zur Erfüllung individueller Kundenwünsche. - 2009. - X, 271 S., zahlr. Abb.
ISBN **978-3-7983-2157-1** vergriffen

**10: Bensel, Philipp: Geschäftsmodelle von Logistikdienstleistern im Umfeld des Ubiquitous Computing**. - 2009. - XIV, 247 S.
ISBN **978-3-7983-2166-3** EUR **5,00**

**11: Bohn, Michael: Logistik im Kontext des ausländischen Markteintritts**. Entwicklung von Gestaltungsempfehlungen für den ausländischen Markteintritt unter besonderer Berücksichtigung der Erfolgskomponente Logistik. - 2009. - XVIII, 334 S., zahlr. Abb. u. Tab.
ISBN **978-3-7983-2179-3** EUR **5,00**

**12: Sommer-Dittrich, Thomas: Wandlungsfähige Logistiksysteme in einer nachhaltigen Kreislaufwirtschaft**. - 2010. - 215 S., zahlr. Abb. u. Tab.
ISBN **978-3-7983-2200-4** EUR **5,00**

**13: Kerner, Jürgen Andreas: Beschaffung im Eigenmarkengeschäft des Bekleidungshandels**. Ein theoretischer und fallstudienbasierter Beitrag zur Lösung ausgewählter Probleme der Prozessplanung. - 2010. - XX, 207 S..
ISBN **978-3-7983-2212-7** EUR **5,00**

**14: Fürstenberg, Frank: Der Beitrag serviceorientierter IT-Architekturen zu integrierten Kontraktlogistikdienstleistungen**. - 2010. - XVIII, 244 S., zahlr. Abb.
ISBN **978-3-7983-2227-1** EUR **5,00**

**15: Fendt, Thomas: Introducing Electronic Supply Chain Collaboration in China – Evidence from Manufacturing Industries**. - 2010. - XII, 219, 53 S., Anh.
ISBN **978-3-7983-2243-1** EUR **5,00**

**16: Franke, Peter D.: Internationalisierung der Kontraktlogistik**. Entwicklung eines Instrumentariums zur Länderselektion. - 2011. - XV, 217 S., zahlr. Abb. u. Tab.
ISBN **978-3-7983-2296-7** EUR **5,00**

**17: Tentrop, Friedrich: Entwicklung eines integrierten Gestaltungsansatzes der Produktionslogistik**. - 2011. - XV, 227 S., zahlr. Abb.
ISBN **978-3-7983-2317-9** EUR **5,00**

**18: Nagel, Arnfried: Logistik im Kontext der Nachhaltigkeit.** Ökologische Nachhaltigkeit als Zielgröße bei der Gestaltung logistischer Netzwerke. - 2011. - XV, 228 S., zahlr. Abb. u. Tab.
ISBN **978-3-7983-2383-4** EUR **5,00**

**19: Grig, Roman: Governance-Strukturen in der maritimen Transportkette**. Agentenbasierte Modellierung des Akteursverhaltens im Extended Gate. - 2012. - XVI, 373 S.
ISBN **978-3-7983-2384-1** EUR **5,00**

**20: Keßler, Martin: Gestaltung von Logistiknetzwerken für die humanitäre Versorgung in Entwicklungsländern Afrikas**. - 2012. - XIV, 355 S.
ISBN **978-3-7983-2426-8** (print) EUR **5,00**
ISBN **978-3-7983-2427-5** (online)

**21: Schwarz, Jennifer Rebecca: Humanitäre Logistik für die Versorgungsproblematik in Subsahara-Afrika.** Aufbau von Logistikkapazität durch Wissenstransfer. - 2012. - XVIII, 336 S.
ISBN **978-3-7983-2444-2** (print) EUR **5,00**
ISBN **978-3-7983-2445-9** (online)

**22: Rief, Daniel: Markteintritt in China.** Flexibilität und Integration als Erfolgsfaktoren in einer dynamischen und komplexen Marktumgebung. - 2013. - XIX, 235 S.
ISBN **978-3-7983-2482-4** EUR **20,90**

**23: Richter, Markus: Nutzenoptimierter RFID-Einsatz in der Logistik.** Eine Handlungsempfehlung zur Lokalisierung und Bewertung der Nutzenpotenziale von RFID-Anwendungen. - 2013. - XIX, 235 S.
ISBN **978-3-7983-2523-4** (print) EUR **21,90**
ISBN **978-3-7983-2524-1** (online)

**24: Huynh, Thu Hang: Beitrag zur Systematisierung von Theorien in der Logistik.** - 2013. - XVII, 429 S.
ISBN 978**-3-7983-2610-1** (print) EUR **21,90**
ISBN **978-3-7983-2611-8** (online)

**25: Fontius, Jörn: Megatrends und Ihre Implikationen für die Logsitik.** Ableitung von Wirkungszusammenhängen. - 2013. - XVII, 217 S.
ISBN **978-3-7983-2634-7** (print) EUR **12,50**
ISBN **978-3-7983-2635-4** (online)

**26: Ouyeder, Ouelid: Strategien für eine nachhaltige Lieferantenentwicklung für die Beschaffung aus Emerging Markets.** - 2013. - X, 279 S.
ISBN **978-3-7983-2658-3** EUR **21,50**

**27: Steffens, Anja: Logistische Wandlungsbefähiger.** Entwicklung eines kontextbasierten Gestaltungsmodells für die industrielle Logistik. - 2014. - XIII, 284 S.
ISBN **978-3-7983-2682-8** EUR **15,50**

**28: Siegmann, Julian B.: Prozessinnovationen bei Logistikdienstleistungsunternehmen**. - 2015. - xxxviii, 245 S.
ISBN **978-3-7983-2737-5** (print) EUR **15,50**
ISBN **978-3-7983-2738-2** (online)

**29: Keitel, Sebastian: Auswirkungen disaggregierter Regulierung auf die Kapazität von Verkehrssektoren.** Eine wettbewerbstheoretische und empirische Untersuchung am Beispiel des Luftverkehrssektors. - 2015. - IX, 252 S.
ISBN **978-3-7983-2749-8** (print) EUR **15,50**
ISBN **978-3-7983-2750-4** (online)

**30: Campos, Juliana Kucht: Integrated Framework for Managing Sustainable Supply Chain Practices**. - 2015. - xii, 121 S.
ISBN **978-3-7983-2783-2** (print) EUR **10,50**
ISBN **978-3-7983-2784-9** (online)

**31: Spiegel, Timo U.:Technologieorientiertes Service Engineering in der Kontraktlogistik**. Konzeption eines Gestaltungsmodells für die systematische Entwicklung technologiebasierter Logistikdienstleistungen. - 2016. - x, 295 S.
ISBN **978-3-7983-2807-5** (print) EUR **15,50**
ISBN **978-3-7983-2808-2** (online)

**32: Figiel, Anna: Transportmanagement in der schnelldrehenden Konsumgüterindustrie.** Entwicklung eines Gestaltungsansatzes zur Integration von Transport und Logistik. - 2016. - XVIII, 227 S.
ISBN **978-3-7983-2816-7** (print) EUR **14,50**
ISBN **978-3-7983-2817-4** (online)

**33: Durach, Christian F.: A Theoretical and Practical Contribution to Supply Chain Robustness.** Developing a Schema for Robustness in Dyads. - 2016. - viii, 183 S.
ISBN **978-3-7983-2812-9** (print) EUR **13,50**
ISBN **978-3-7983-2813-6** (online)

**34: Blome, Hendrik: Logistische Optionen für eine nachhaltige Versorgung von Subsahara-Afrika.** Ein Beitrag zur Humanitären Logistik. - 2016. - XVII, 315 S.
ISBN **978-3-7983-2840-2** (print) EUR **16,50**
ISBN **978-3-7983-2841-9** (online)

**35: Kucht Campos, Juliana: A methodology for planning sustainable supply chain initiatives.** - 2016. - xviii, 326 S.
ISBN **978-3-7983-2860-0** (print) EUR **16,50**
ISBN **978-3-7983-2861-7** (online)

**36: Wutke, Sebastian: Entwicklung eines Gestaltungsmodells zur Berücksichtigung von Nachhaltigkeit bei der Ausschreibung und Vergabe logistischer Leistungen im Straßengüterverkehr**. - 2017. - X, 299 S.
ISBN **978-3-7983-2862-4** (print) EUR **15,50**
ISBN **978-3-7983-2863-1** (online)

**37: Schöder, Dustin: Technisch-wirtschaftliche Bewertung des Einsatzes von batterieelektrischen Nutzfahrzeugen in der Distribution von Konsumgütern**. - 2017. - XV, 287 S.
ISBN **978-3-7983-2920-1** (print) EUR **15,50**
ISBN **978-3-7983-2921-8** (online)

**38: Roy, Daniel Thomas: Industrie 4.0 – Gestaltung cyber-physischer Logistiksysteme zur Unterstützung des Logistikmanagements in der Smart Factory**. - 2017. - XVI, 204 S.
ISBN **978-3-7983-2944-7** (print) EUR **14,50**
ISBN **978-3-7983-2945-4** (online)

**39: Ding, Feng: Developing e-commerce logistics in cross-border relation.** - 2018. - XV, 186 S.
ISBN 978-3-7983-2972-0 (print) EUR **14,50**
ISBN 978-3-7983-2973-7 (online)

**40: Nitsche, Benjamin: Development of an assessment tool to control supply chain volatility**. - 2019. - VII, 161 S.
ISBN 978-3-7983-3054-2 (print) EUR **12,50**
ISBN 978-3-7983-3055-9 (online)

**41: Mittag, Peter: Entwicklung eines anwendungsorientierten Gestaltungsansatzes zur Geschäftsmodellinnovation mithilfe von smarten Produkt-Service-Systemen**. - 2019. - XXXIII, 201 S.
ISBN 978-3-7983-3048-1 (print) EUR **14,00**
ISBN 978-3-7983-3049-8 (online)

**42: Reipert, Jan: Open Innovation in der Logistik – Entwicklung eines Gestaltungsmodells zum Aufbau eines offenen Innovationsmanagements in logistischen Dienstleistungsunternehmen**. - 2019. - X, 206, XLVIII S.
ISBN 978-3-7983-3062-7 (print) EUR **10,50**
ISBN 978-3-7983-3063-4 (online)

Universitätsverlag der TU Berlin

## Conceptualizing and capturing digital transformation's customer value – a logistics and supply chain management perspective

This thesis aims to add knowledge contributing to the question of how digital transformation technologies can help to increase customer value in logistics and supply chain management (L&SCM), and how manufacturing companies can mindfully use them. The output is an architectural framework that proposes performance components, approaches and methodologies that can support in capturing this customer value. As a basis for the framework, this research first deduces and presents the underlying definition of digital transformation and describes its potential for, as well as current barriers for its application in L&SCM. Subsequently, the study uses a systematic literature review to identify nine underlying digital transformation technology bundles. These are auto-identification technologies, information and communication technologies, cloud, cyber physical systems, analytics, distributed ledger, automation technologies, augmented and virtual reality, and additive manufacturing. These technologies serve as inputs for a nominal group technique workshop to conceptualize the dimensions of customer value and the additional expert interviews to derive how advanced manufacturing companies capture it.

ISBN 978-3-7983-3177-8 (print)
ISBN 978-3-7983-3178-5 (online)

ISBN 978-3-7983-3177-8

http://verlag.tu-berlin.de