Digital Supply Chains

Key to resilience and new business models

Götz G. Wehberg

- 2nd Edition -

For Alexandra, Finn and Ole in in love.

Digital Supply Chains –
Key to resilience and new business models
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Preface

Over the past 20 years, a variety of new technologies developed. Under the heading "Industry 4.0", Germany and other countries want to leverage these opportunities. They aim at securing their competitiveness and prosperity. The first industrial revolution introduced mechanization. Then, mass production and automation followed. The focus was on large scale and efficiency of human resources. Now, the fourth revolution aims at the flexibility of the value chain. This means mobilization of machines and objects. And it offers great opportunities for the management of the flow of goods and information associated. It is time for digital supply chains!

Four figures in this context: Estimates of the installed base of connected devices currently suggest 20 billion worldwide. Thereof, just some 25 percent go back to industrial appliances (IHS Technology 2015). By 2025, this number of connected things is expected to be some 100 billion. And the industrial share will be around 50 percent. The role of supply chain management for such world of connected things is rather underestimated.

Taking into account these new possibilities, I would like to combine technology and business perspectives with this publication. Supply chain management is mostly of a complex nature. And it is becoming more and more difficult to deal with such complexity. If you look into details you find out that, today, supply chains are challenged by mass customization and, thus, an increasingly complex product portfolio and a higher number of rush orders or change requests, accordingly. Disruptions along the chain become more difficult to handle, for example because of breakdowns of logistics infrastructure, electricity blackouts, bio catastrophes and terror attacks. And also factors from the inner value chain tend to become more volatile, in terms of unplanned production shut downs, bottlenecks at suppliers or sickness of staff. Moreover, supply chain management is a key facilitator for new, digital business models.

Current practices, however, do not respond to these challenges, properly. Established supply chain planning tools, for example, typically refer to traditional concepts of material resource planning. They do not leverage latest technology such as low-cost sensors and predictive analytics. This is often not good enough to help, effectively. And there is also no mature supply chain theory existing, which helps from a kind of academic standpoint. This is why I have complemented the discussion by relevant concepts and theories, where available. As I suggest, there is a value added of understanding the roots of digital supply chains in terms of its scientific rationale.

The gap between the explosive increase of supply chain complexity on the one hand and the lack of solutions on the other hand is the starting point for this publication in its first part. The aim is to have a clear idea of the interrelations between complexity and supply chain management. Such concept is based on a resilient understanding. Since the physical and information flow must always be considered together, the latest information processing technology must be taken into account. Modern IT such as the Internet of Things, the Digital Twin and Cloud Computing is put into context as well as relevant IT standards, for example big data reference architecture.

Since digital supply chain management has to build on existing approaches, in the second part the existing understandings of supply chain management are briefly systematized. Building on this, a resilient understanding is being presented. The reference framework of digital supply chains is introduced.

The subsequent remarks of the third and fourth parts aim to fill this frame of reference with content. The analysis focuses on the information and planning system of supply chain management in particular. The frame reflects essential patterns with means of supply chain profiles, the knowledge of which forms the basis for handling complexity. Selected use cases illustrate the frame and point the way towards digitalization. While the first edition of this book was published in German language in 2015, this second edition has been translated to English and has been enriched by further practical experience and use cases. This is the basis for further development including a democratic review via my think tank-website and the supply chain community associated.

In the context of a resilient understanding, Part 4 highlights the development of supply chains over time in terms of the concrete lifecycles and phases. Based on this, guiding principles for the development of digital supply chains are explained. Perspectives for a future supply chain management will follow in the course of the fifth part, which concludes the presentation.

The publication is teamwork. My thanks to both my customers on the one hand as well as my family, friends and colleagues on the other hand. Particularly noteworthy in this context are Prof. Ingrid Göpfert, Prof. Stefan Spinler and Prof. Ulrich Thonemann. Without them all, this publication would not have come about.

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(https://www.youtube.com/watch?v=WZvGPXLhhSA)

In a nutshell — 10 theses on digital supply chains

In the following selected theses of this publication are summarized. It is about encouraging reading and providing food for thoughts:

1. **Digital supply chains mean innovation**. Without digital supply chains new business models do not work. For example, the Internet of Services offers additional potential for differentiation in competition.

2. **Digital supply chains cope with complexity**. Its digital twin provides answers to increasing complexity, asking for more resilience. It answers to an increasing number of disruptions along the supply chain and the individualization of products in particular.

3. **Digital supply chains are more than cyber-physical systems**. It is not limited to new technologies but is to be understood as a holistic business solution. Customers more and more look for total transparency and immediate delivery in the future

4. **Digital supply chains set efficiency standards**. They reduce transaction costs and support resilience as well as flexibility, e.g. with respect to batch size one and scalable structures. Future supply chain organizations need significantly less resources than today.

5. **Digital supply chains need a concept**. A frame of reference provides design support for managing complexity and closing the integration gap. Supply chain management in many organization is pre-mature so that a proper concept supports both to fix the basics as well as to make use of digitalization.

6. **Digital supply chains leverage on self-organization**. The leadership sets guidelines for steering, design and development and works through shared values and management by exception. Supply chain operations are highly automated.

7. **Digital supply chains are based on pattern recognition**. To cope complexity, artificial intelligence and big data are used to identify effective algorithms. While artificial intelligence helped to forecast in the past it will adopt forecast methodology in the future.

8. **Digital supply chain management is not limited to delivery**. End-to-end supply chain models help to connect the dots across functions and borders. Digital supply chains involve Sales, Production, Procurement and R&D in particular.

9. **Digital supply chains must be specific**. The operating model and execution roadmap are to be developed on a company-specific basis, e.g. matching the existing IT landscape and meeting individual customer requirements.

10. **Digital supply chains are at the beginning**. Learning new skills will be key to success of the transformation and building a comprehensive digital twin of supply chains. Therefore, we should think big, start small and scale fast.

Part 1: Why supply chain complexity matters

1 The complexity issue

The complexity problem is now on everyone's lips. The increasing scope of coordination and thus efforts to coordinate supply chains are ultimately the result of a growing complexity of the in- and environment of enterprises (Ulrich / Probst 1991). **Complexity** presents itself as the product of corresponding dynamics and diversity. The increasing number and variety of relevant variables as well as the heterogeneity of their relationships characterize diversity. Dynamics reflect the degree of renewal of supply chain relevant elements as well as their relationships and effects over time. Also, well known and often used is the abbreviation **VUCA**, which stands for volatility, uncertainty, complexity and ambiguity. The VUCA term uses slightly different definitions and there is little value in having a discussion about nomenclature. Dynamics and diversity, therefore, do represent the substantial drivers of complexity in the following.

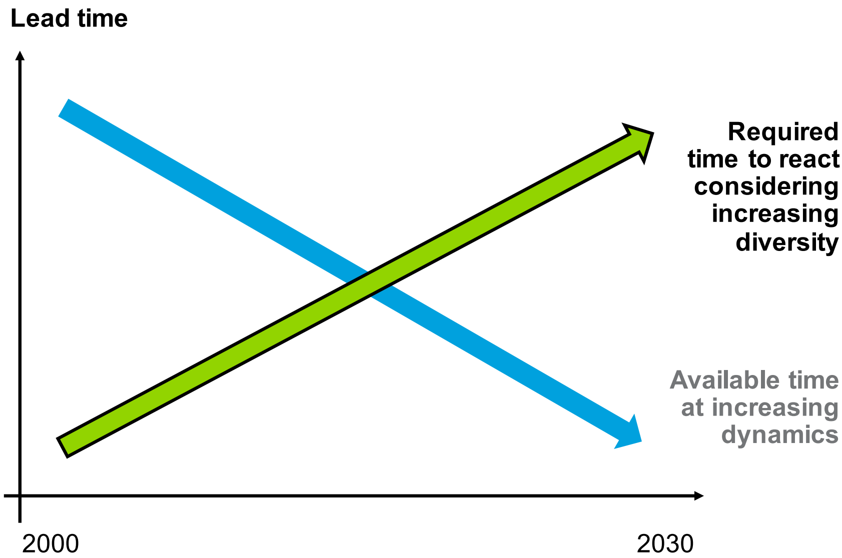
If we now visualize the development of the complexity of supply chain-related parameters in recent years, we can see an overall rising trend. The higher complexity is requiring more time to analyse and make decisions. On the other hand, the available response time of supply chain managers decreases with higher dynamics. A kind of **time shear** opens a gap (Figure 1.1).

For supply chain practitioners, the aforementioned time gap appears in the form of a whole series of relevant **megatrends** such as digitalization, individualization, need for data security, scarcity of resources, service competition, terrorism, tax optimization and sustainability. Moreover, unforeseen **disruptions** in the daily business impact the supply chain more often. For example, a PPDS cycle typically had a freeze some years ago. In the meanwhile, many companies increasingly face rush orders, re-prioritization and change requests during this cycle. They cannot re-do the PPDS as fast as new requests are coming in. Issues accumulate. Stocks arise, create bottlenecks within the process, extend respond times and make the situation even worse. The so-called bullwhip effect materializes. Other examples for potential disruptions include infrastructure breakdowns, bio-catastrophes and terror attacks. And so, there are a number of other factors that essentially describe a development that supply chain management in practice has become increasingly complex in recent years and will continue to do so in the future.

In highly complex, non-trivial systems, statements about the effectiveness and efficiency of supply chain management can no longer be described as linear if-then relationships. In addition, long-term impacts often do not correspond to short-term effects. As consequence, a complete analysis of the supply chain system is impossible. Supply chain management acts to a certain extent "blindly". In other words, **synoptic planning** is no longer possible (Probst 1981).

Ten Hompel (2014) speaks in this context about a **hydrostatic paradox**. The classical planning of material flow systems is essentially based on so-called marginal cost calculation. In this context, the maximum performance has to be provided as the volume delivered per unit of time. The dilemma of this analytical approach in a complex environment lies in the lack of controllability of the marginal power, which means in its barely existing flexibility and resilience.

Figure 1.1 The time gap of supply chain management (following Bleicher 1995, modified by Wehberg 1997, 2015)



Supply chain resilience thus means to be able to handle unforeseen events such as logistics infrastructure breakdowns, bio catastrophes or terror attacks (see also Weick / Sutcliffe 2001). Over and beyond external disruptions, resilience also includes the capability to cope with increasing internal complexity such as the climbing number of make-to-order products and rush-orders. In a way, of course, such internal disruptors are also a response to external developments. Bottom line, a sufficient resilience allows the companies to maintain a resonable level of effectiveness and efficiency of their supply chain. Resilience includes both an active dimension being addressed by the concept of agility as well as a reactive one called robustness. While resilience is a characteristic of supply chain potentials and activities, flexibility means service quality as performance criteria.

Even if the individual system details can no longer be fully grasped or mastered, supply chain management generally tends to increase or decrease the extent of its complexity. **Complexity mastery** is replaced by complexity management or handling. "The need for coping with complexity arises from the realization that every [open] system is embedded in an environment that usually has many behaviours. If a system wants to survive in its environment, it must be able to 'oppose' these behavioural possibilities." (Probst 1981, translated) The extent to which supply chain management deals with complexity determines its efficiency and effectiveness, and thus its contribution to the overall success of the company (Bleicher 1995, Kirsch 1984, Ulrich / Probst 1991).

The traditionally propagated way of supply chain management was the avoidance or reduction of complexity, for example by external regulation and specialization. However, such an approach is inappropriate to provide the necessary resilience and variety in the supply chain system necessary for the survival of the enterprise. Complexity management should, therefore, not always mean the reduction of complexity, but may also imply its conscious increase. The ability to increase complexity is even a central prerequisite for the development and survival of open systems, such as supply chains par excellence (Röpke 1977). On the other side, an unconditional flexibility of supply chains, as is often discussed, is not always appropriate. For supply chains, complexity management in this sense means to handle the interplay between complexity increase and reduction in the form of an **agile development**, such as a trial-and-error process. It must take steps to reduce or increase complexity and at the right time, to the right extent. Although supply chain management does not have complete knowledge of the system's interrelationships, it can recognize certain rules or patterns of order resulting from the interplay of the structures and behaviour of the system or the members of the system, and align its actions accordingly. Such an approach outlines the subject area of digital supply chain management as a whole.

2 Need for a framework

The high importance attributed to the **complexity management of supply chains** raises the question of an adequate design. This problem has not yet been fully addressed by scientific efforts. As will be proved in the course of the second part, business sciences offer little theoretical-conceptual support regarding the handling of supply chain complexity. Even if the development of supply chains management is addressed, as for example with **Copacino** in 1992, **Dubbert** 1991, **Ihde** 1991, **Weber / Kummer** 1994 and **Pfohl** 199l, a comprehensive theoretical appreciation of complexity management for supply chains hardly takes place. In addition, the contributions are often limited to selected management subsystems, such as the organization and human resources, or to a subarea of supply chains, such as production logistics. The most comprehensive approaches are provided by the conceptual work of Warnecke, Wildemann, Fey as well as Smith and Ptak. In recent years, the platform Industry 4.0, acatech and Fraunhofer emphasize the importance of cyber-physical systems for such complexity management.

Warnecke uses his concept of the fractal factory to design a system for production logistics. The fractal structure offers a hierarchizing of the manufacturing organization and enables sufficient complexity in this area via decentralized control loops (Warnecke, 1992). **Wildemann** offers the "Modular Factory" in response to the growing complexity of manufacturing. With his concept of manufacturing segmentation, he offers an organizational principle based on flexibility and process orientation for production (logistics). His concept implies complexity-increasing approaches in particular in connection with the creation of structured networking and self-regulating, partially autonomous subsystems (Wildemann 1994). The implementation of Warneckes and Wildemann's ideas are made possible by the use of cyber-physical systems in their pure variety, so that Warneckes and Wildemann's reflections through the 4th Industrial Revolution experienced a sort of renaissance for production. From the point of view of supply chain practice, it has been noted that both approaches, by Wildemann and by Warnecke, have always been considered very important and relevant. The appreciation and interest of the supply chain practitioner in concepts such as Fractal Factory or Modular Factory prove that the desire for solutions to dealing with increasing complexity is very strong and increasing. In this respect, Warnecke and Wildemann set the central milestones for the development of complexity management in production. Both approaches offer principles that can also be rolled out to the entire supply chain.

Fey (1989) embeds his concept of integrated supply chain management in the company's management system and derives development steps for supply chains (Kummer 1992). In doing so, he takes aspects of resilience into account as he sheds light on the development of supply chains from a traditional to a cross-sectional understanding. Fey concentrates his statements on the evolution of supply chain management. Like Warnecke and Wildemann, Fey also concentrates mainly on the area of production logistics.

In my publications of 1994 and 1997 (Wehberg 1994, 1997) I am picking up the aforementioned approaches of Warnecke, Wildemann and Fey amongst others, to design a management concept for the complexity management of the entire supply chain or its resilience, respectively. In the **first edition of this publication** (Wehberg 2015), I am then considering the possibilities of Industry 4.0 or digitalization, respectively. By doing so, I am trying to combine principles of a demand driven and resilient understanding. In this second edition, further practical experience from another four years of transforming supply chains as a consultant is being considered (e.g. Wehberg 2018, Wehberg 2018b, Wehberg / Berger 2018). This includes cooperation with technology providers such as SAP Leonardo and Siemens Mindsphere, in particular.

In 1996, **Beckmann** developed a prototyping approach for supply chain planning based on agile principles. Later on, the resilience of organizations were addressed by **Bell** (2002) amongst others in the light of the terrible attacks of 11. September 2001. In particular, resilient supply chains became a focus of interest, e.g. by **Christopher / Pack** (2004). These publications focused on the vulnerability of supply chains in case of unexpected events such as terror attacks. While the theoretical fundament of these approaches was not broadly elaborated, they are primarily focusing on risk mitigation. New opportunities generated by digital business models were not incorporated comprehensively.

Smith and Ptak (2011) then deployed the ideas of de-coupling, postponement, etc. to MRP-based standard software for supply chain planning, in terms of a demand driven material resource planning. Their concept helped to develop standard solutions in planning tools and to apply relevant concepts, practically. A full leverage of digitalization potentials, though, still has to be provided from both sides Smith`s and Ptak`s Demand Driven Institute as well as respective vendors, which they are working on. E.g., **SAP** has announced to consider a demand driven approach within its IBP tool set and is working on it.

Among others, the initiative of the Federal Government "**Platform Industry 4.0**" (with the participation of BITKOM, VDMA and ZVEI), the German Academy of Engineering, **acatech**, and the **Fraunhofer Gesellschaft** (exemplified by acatech

2015, Bullinger Hompel, 2007 and ten Hompel 2014), all three have helped to structure the conception of Industry 4.0 in recent years and have emphasized the significance for supply chain management in particular. For example, ten Hompel early recognized the importance of RFID technology as a kind of precursor of cyber-physical systems (ten Hompel, Bluechter, Franzke, 2008). In this context, the federal initiative, acatech and Fraunhofer - each for themselves - are central points of contact for the idea of Industry 4.0 with its technological basis.

It should be noted that there is still a lack of understanding of complexity management for supply chains in many respects. There is a strong need for a frame of reference of digital supply chain management that supports decisions and resilience in particular. From an IT angle, such framework has been drafted in terms of **RAMI 4.0** (Reference Architecture Model Industry 4.0). It is currently maturing through the development of a big data architecture framework. The latter one typically includes a large number of vendors, while the global players in that market are currently trying to insource, subsequently, and build a track record of use cases. Prospectively, in some years such IT frameworks will be off-the-shelves and commoditized. The business and technological dimension, however, do not replace one another but complement each other. The key question thus is how digital technology can support competitiveness and enable new business models, which still needs some answers and conceptual foundation.

In particular, there is a lack of a comprehensive empirical foundation of guiding principles on complexity management in supply chains, to which only initial investigations are currently known. For the future, the goal must therefore be to further develop the concept for supply chain management 4.0 or **digital supply chains**, respectively.

A purely theoretical discussion of scientific fundamentals is of little value, without being challenged from a practical perspective. **Practical relevance** arises e.g. by questioning and putting into context with application examples. On the other hand, reporting selected case studies itself is not very creative. This is why we will try to consider both perspectives in a balanced manner.

In the following, the terms “supply chain” or “logistics” as well as the expressions “resilient”, “evolutionary” or “change oriented” are used in a somewhat interchangeable way. This is not entirely precise from a scientific point of view. However, this blurring should be overlooked insofar as the discussion does not directly refer to its scientific basis.

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Part 2: Where we come from

In the first part, key sources of logistics literature have already been addressed to make clear that the field of digital supply chains is, so far, a little touched one.

The question what is special about digital supply chains should not be confused with an investigation of the identity of supply chain management itself. **Supply chain theory** is facing a tough test. Scientists argue with neighboured business studies, such as production, about the original subject of supply chain management (for its terms, see Chapter 2 of this part). Occasionally even the question is raised, if supply chain management is not "old wine in new hoses". This shows that a broad consensus on what supply chain management is now accurate has not yet been achieved. The attempts to answer are rare and not seldom inadequately sound (however, Göpfert 1996).

In the following it will be explained why the existing understandings of supply chain management are not suitable for coping with complexity. The various definitions are classified in the sense of an overall view. The understanding of supply chain management has always been influenced by certain megatrends, also referred to as "paradigm" or "myth". Since the end of the last century, five main trends have been identified (Fey 1989, Kummer 1992 b):

To a certain extent as the source of these current paradigms, "**Scientific Management**" shaped the functional specialization of companies (Taylor 1911) at the beginning of the last century. The core idea of this development direction is to use task-sharing as efficiently as possible through specialization. The institutional separation of management and execution functions goes back to this Tayloristic approach. For example, concepts that are still applied today and are based on functional specialization are experience curve effects of companies. The functional specialization was followed by a **product and customer specialization**, which is mainly expressed in today's marketing ideas (Gutenberg 1955, Meffert 1977). This was the basis of **process specialization**, which could significantly contribute to the profiling of supply chain management as an independent business function. In the last 30 years gaining importance, but often treated without the necessary theoretical foundations, the change of businesses is characterized. It is expressed, for example, by slogans like "**Management of Change**" or "Chaos Management" and deals above all with the problems of complexity handling and change (Bleicher 1979 and 1995, Kirsch 1992, Kirsch et al. Probst, 1991).

Moreover, one mainstream of business activity is the specialization on relationships, which focuses on the development of a holistic reference framework for the design of highly complex systems (Diller 1994, Sydow 1993). For example, the current development of the **transaction cost theory** is associated with it and tries to explain the functionality of networks or eco systems. Since the establishment and maintenance of such **eco systems** can ultimately be understood as a response to a more complex corporate environment, relationship specialization can be interpreted as a specific form of expression of change (Wehberg 1994). If we start from the megatrends of business administration, then they can be assigned to the different understandings of supply chain management. The criticism of one approach shows the advantages of the following ones (Weber / Kummer 1994, supplemented by Göpfert / Wehberg 1996).

1 Existing approaches

The **transfer-oriented understanding** of supply chain management characterizes all "transport, storage and transhipment processes in the real goods sector in and between social systems" (Arnold 1988, after Weber 1993b, translated). It is currently the most widespread in the field of supply chain management. It thus understands physical transfer functions in the form of purposeful space and time bridging as the task of supply chain management. And it thus focuses on the execution system of a company. In many instances, the expression “logistics” is used in this context, rather than “supply chain management”. But of course, it is the understanding that counts and not the nomenclature. Today, many supply chain managers decorate their role as supply chain management while following aforementioned understanding.

The transfer-oriented understanding paves the way for a closer study with a group of services that has often been neglected in the past. The mere renaming of already existing functions, such as transport and storage, offers possibly positive loading effects (Weber / Kummer, 1994). However, there is neither great practical benefit nor theoretical cognitive value. Such functionally specialized task view, at best, offers efficiency advantages, for example due to experience curve effects. The functional specialization also finds expression in technical optimization efforts for individual process steps, such as the construction of dump trucks, industrial conveyors, pre-distribution systems of commissioning, etc. It reflects incompletely the range of tasks of supply chain management.

In contrast to the transfer-oriented approach, the **process-oriented supply chain management** includes not only the spatial and temporal transformation functions. It considers the operative steering functions relating to the flow of goods. The latter include, for example, production planning and scheduling as well as dispatch control. The aim of supply chain management in this sense is the coordination of the entire process chain in an end-to-end fashion. The scope goes from upstream suppliers to production and customers right through to the disposal. By avoiding isolated applications, it aims to realize efficiency gains beyond functional specialization. The just-in-time delivery principle (Weber / Kummer 1994), can be cited as a representative example of process-oriented understanding. Just-in-time seeks complete control of a significant part of the material flow and ultimately identifies production-synchronous procurement. And managing the relationship between sales and manufacturing is certainly at the heart of supply chain management, from a process-oriented angle.

As a typical example of such a supply chain management definition that reflects this flow-oriented approach, Pfohl (1990, translated) mentions that of the **Council of Supply Chain Management**: "Supply chain management ... is ... the term describing the process from planning, implementing, and controlling the efficient, … and cost-effective supply of raw materials, in-process inventory, finished goods, and related information from point of origin to the point of consumption".

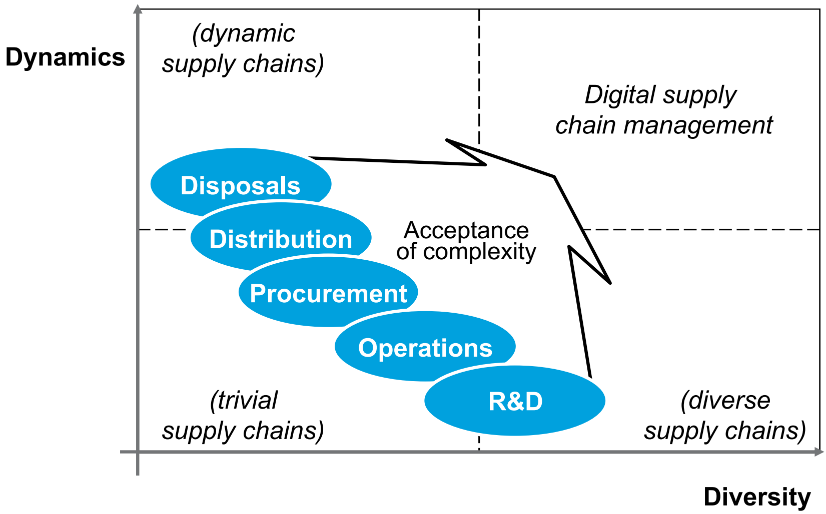
Against this background, we can see the "**system thinking**" of supply chain management: The supply chain is then described as "a number of interrelated parts that operate for a common purpose" (Forrester 1972). From a system perspective, in addition to the elements and relationships of the system itself, it also has to take into account relations with its surrounding system (Pfohl 1990). Process-oriented understanding in this sense tries to holistically grasp the interdependencies and the complexity of supply chain tasks. Due to its limitation to operational tasks, however, it offers only weak design assistance for the development of supply chains. Thus, the complexity management of supply chains has to be regarded as a primarily normative-strategic problem.

The **demand driven supply chain management** also considers strategic aspects. It takes into account that relevant parameters do not determine the potential for the whole. Typically, success depends to a large extent on external factors, such as customers, competitors and suppliers (Weber / Kummer 1990). Therefore, this approach is based on the concept of "**strategic management**" by Ansoff, Declerck and Hayes in 1976. This concept of strategic corporate governance has now reached a high level of diffusion.

In business reality, the discussion about the strategic importance of supply chain management goes back to the 80s and 90s. While in the 1960s supplier markets were primarily driven by strong demand, it changed towards **customer markets** at the beginning of the 1980s and 1990s. In addition to the product features, service and supply chain characteristics have increasingly played a role for differentiation in competition. Supply chain service has become the subject of strategic considerations. Concepts such as **marketing logistics** and strategic supply chain management were developed and implemented.

However, there are increasing voices that critically raise doubts about the prevalent mechanistic feasibility or "**mastery of control**" of aforementioned understanding (Antoni 1985 and 1986, Bleicher 1989, Mann 1988 and 1995, Servatius 1991 and Stachle 1989). The latter seems to be typical for at least a large part of the supply chain theory that corresponds to such demand driven understanding. Last but not least, it explains the strong need to reduce system complexity instead of increasing it where necessary. It goes hand in hand with the desire to reduce uncertainty and increase control.

Figure 1.1 Supply chain integration through acceptance and management of complexity



In this context, the thesis of the **integration deficit** of logistics applies (Klaus 1994): Countless definitions of supply chain management as well as declarations of managers reproduce the holistic claim: Flows of material and goods are to be combined across functions and institutions to create a system-wide optimum. However, to date, supply chain management is organized in many companies as "functions" logistics, e.g. for “SCOR” functions. It is common practice to focus on the three planning areas of procurement, production and distribution logistics in a comparatively isolated way. More or less, they are based on their own objectives, optimization rules and databases. Integration are much more often an idea than reality. The potential of supply chain management is far from exhausted. In reality, a significant “**knowing-doing gap**” (implementation gap) is associated with it.

The knowing-doing gap then results in a chaotic approach to supply chain management. It leads to bullwhip effect and inappropriate service levels for customers. A common reaction in this situation is to increase inventories as the management wishes to buffer some of the day-to-day problems, however that makes it even worse because lead times prolong and flexibility decreases.

A resilient understanding of supply chain management promises to close the integration gap. "The perceived dynamic plays the role of the trigger for system strategies that cope with complexity" (Bleicher 1994, translated). Good, results-oriented strategy exercises always begin with a thorough discussion of trends, disruptions and challenges. Appropriate supply chain strategies find suitable answers to this kind of complexity drivers. In addition to a "Knowing-Doing-Gap", there is a "**seeing-knowing gap**" (meaning gap), which describes the delta between data availability and insight, accordingly.

The seeing-knowing gap does not mean, however, that the potential of digital supply chains can be realized with better planning and forecasting only. In a complex world, the ability to predict is limited. And thus, supply chain management needs to seek for new and better ways to handle complexity. The seeing-knowing gap, therefore, refers to the perception and acknowledgement of the relevant complexity, rather than demand forecasts and its attempts to improve. It is one of the most common misunderstandings to believe the potential of digitalization is mainly to use predictive analytics for improving forecasts. You can call this the **forecast myth**. It is exactly the opposite, complex supply chains handle demand characteristics that you cannot forecast, independent how smart you are.

2 Resilient understanding

2.1 Roots

To avoid misunderstandings, basic concepts of a demand driven understanding of supply chain management should be contrasted with the roots of a resilient approach, first. The resilient understanding (Göpfert / Wehberg 1996, Göpfert 2000 and Wehberg 1994 and 1997) refers to a "holistic-evolutionary management theory" (Servatius 1991):

Mandeville laid a first important cornerstone of this theory through his publication "**The Fable of the Bees**", in which he developed already at the beginning of the 18th century, the twin idea of evolution and the spontaneous formation of order (v. Hayek 1969b, Kieser 1988). In 1767, Ferguson brought up Mandeville's idea of the short-term formula that although order may be the result of human action, it must not be human intention (Ferguson 1767 and 1966, v. Hayek 1969b). Darwin, who is today regarded as co-founder of evolutionary biology and the theory of evolution in general, was also inspired by these first evolutionary steps (Darwin 1859 and 1967, Riedl 1987). The conception of this theory of development builds on the fundamental idea that a mechanism of multiplication of transferred variants and its competitive selection, over time produce a wide variety of structures which show themselves to be suitable in complex environments (v. Hayek 1972). This basic idea is also referred to as the **evolutionary principle**. Consequently, system complexity becomes the variable of the evolutionary process (Röpke 1977). It characterizes a system of being able to accept a large number of different states in a given period of time (Ulrich / Probst 1991). Schumpeter (1950) is probably one of the most important representatives of the theory of evolution in the context of economic scientific research efforts with his process of **creative destruction**, which is regarded as the core element of technological change and thus as the source of economic development.

The theory of evolution was often misunderstood. Numerous erroneous interpretations of this theory are responsible for the **misconception** that it consists of the assertion of the sequence of particular types of organisms that gradually morph into one another. This is not, however, the theory of evolution, but the application of the theory to the individual events, which take place on Earth for approximately the last two billion years (v. Hayek 1972). It is often misconstrued that evolutionary mechanisms in social systems should act less on the level of individuals and more on institutions and their behaviour (Malik 1984, Sprüngli 1981).

At the same time, nature offers a lot of analogies we can learn from. Let us have a look at the **live of the ants** for example. Harvest ants can promote forestry by accelerating the degradation and conversion of wood. They effectively eliminate other, harmful insects. And the presence of many seed-collecting ants may normally favor production because it counteracts the increase in harmful parasitic beetles.

Ants form highly organized colonies that may occupy large territories and consist of millions of individuals. The colonies are described as superorganisms because the ants appear to operate as a unified entity, collectively working together to support the colon. Their success in so many environments has been attributed to their social organization in terms of swarm intelligence as well as their ability to modify habitats, tap resources and solve complex problems.

What a great supply chain that ants have – its flexibly responding to new challenges, resource efficient and secures the supply of the colon on a highest level. A great example of nature that we can benefit from because we also have to secure supply, be efficient and work flexibly. Our supply chains typically follow the same or very similar principles.

The second historical root of the resileint understanding of supply chain management is **holism**. The essence of this attitude is expressed in the demand for a holistic network of thinking and acting instead of the mechanistic world-picture (Capra 1985). The introduction of holistic thinking into business administration has already taken place through the system-oriented approach developed by Ulrich (1968). However, the influence of holistic principles also changed the system theory (Staehle 1989b). If equilibrium-preserving processes are still the subject of first-order cybernetics, cybernetics of the second order is now primarily concerned with imbalances. And imbalances are a necessary condition for changes in a system (Beer 1972, Kirsch et al., 1979, Vester 1980b, Malik 1984, to Knyphausen 1988 and Schulz 1993). The latter can logically be understood as a science of the design and direction of complex, dynamic systems. It establishes a system theory in the broader sense, which is also called **New Systems Theory** (Probst 1981).

At this point, the transition between holistic and evolutionary approaches becomes fluid (Servatius 1991).

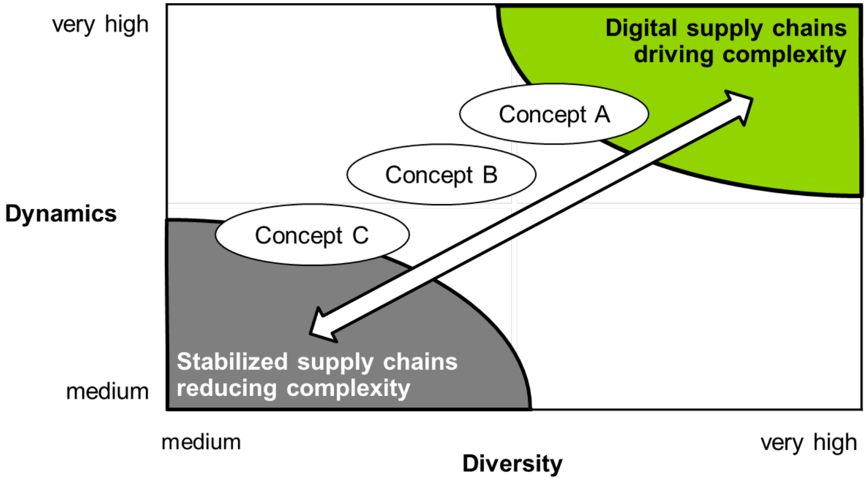
2.2 Integration as core

The adaptation of supply chain structures to changing environmental conditions is usually seen as the task of each subarea, for example, the packaging and warehousing. In the context of a holistic approach, however, this is at the heart of **supply chain integration**. The focus of resilient supply chains thus is based on a kind of meta-management. Supply chain integration in this sense must anticipate adjustments that affect the entire supply chain and drive innovation, accordingly (Bleicher 1979, Wehberg 1994). Designing a future supply chain target operating model means both integration of physical flows as well as of supply chain management itself. The one is a prerequisite for the other, and vice versa.

Küpper talks about controlling instead of integration (Küpper 1987, 1995). According to his ideas, **supply chain controlling** plays a central role in the development of a supply chain (management) system. Similarly, Kirsch (1992) uses the term "Controlling Overlayer". The task of supply chain controlling is characterized by coordinating the management system. It is referred to as secondary coordination, in addition to the primary coordination of the supply chain itself. Moreover, a **system forming** and **system coupling** is being distinguished.

Bleicher's (1979) concept Integrated Management - which is also known as the **St. Gallen Management Concept** - forms a frame of reference for management integration and can be transferred to supply chain integration in particular. For doing so, Bleicher offers a technique for analysing of the entrepreneurial situation in polarized series of tension. This profiling technique supports promising adaptations. It enables statements about the actual and target relationships between intrinsic and external complexity of the supply chain system, which are shown in a simplified way in Figure 2.1. Specifically, the "**stabilized supply chain**" characterizes a relatively low complexity. The "**digital supply chain**" represents a higher complexity of relevant structures. In this context, the term "change" continues to characterize the already mentioned interplay between stability and resilience. In a way, it can be seen as a measure of complexity.

Figure 2.1 Profiling of change (as measure for complexity)



Aforementioned profiling framework has to be enriched with **design principles** or concepts to provide guidance for decision-making and facilitate implementation. The theory of evolution does not characterize a closed statement system. Rather, it encompasses a heterogeneous bundle of approaches. Each individual approach regularly includes a cluster of scientists (Wehberg 1996, based on Semmel 1984) such as the **population ecology** approach, especially after Aldrich, Hannan, Freeman, Kaufman and McKelvey, the **market process** approach with Fehl, Kerber, Kirzner and Lachmann, the **organizational process** approach, especially with Bigelow, Dyllick, Röpke and Zammuto, the **self-organization** approach with the St. Galler Schule under Ulrich on the one hand and the Munich School under Kirsch on the other hand., the **psychological approach** according to Weick u. a. and the **cybernetics** approach, especially with Ashby. There is no need to address these approaches of organizational theory more precisely at this point. The reference made here is sufficient to draft a borderline of the resilient understanding of supply chain management from the understandings so far represented in the literature.

Now, a functional perspective (on what resilient supply chain management does) must be differentiated against an organizational one (who is doing it). How supply chain integration is organized and by whom, finds very different forms in corporate practice. In **large corporations**, business units or divisions typically orchestrate supply chain operations. The development of supply chain management itself is performed at group level. From a corporate perspective, supply chain integration aims at identifying cross-BU trends and clamping functions in terms of size, scale and learning effects. For example, a company-wide consolidation of warehousing or supply chain analytics typically offers such scale. For good governance, it often makes sense to anchor supply chain management a direct report of the chief finance officer. Here, supply chain integration thus depends on the power and capabilities of the corporate function. In **medium-sized companies**, supply chain tasks are often not explicitly anchored, organisationally. Such tasks are being performed as part of traditional sales and production functions and responsibilities. Here, the development of supply chain management is often in the hands of the sales or production manager, which can be the reason why supply chain integration is not properly performed. Last not least, there is a trend towards **4PL** services, fourth party supply chain management. These outsourcing services take over a large part of planning, control and scheduling. It typically includes optimization and thus integration efforts. Like any outsourcing of businesses processes, companies using 4PL have to make sure, they still do have the minimum capabilities to steer their service providers. This is especially true just because 4PLs may commit to performance improvements facilitated by respective contracts, however, they are most likely not prepared to cover the development function in a resilient understanding, comprehensively.

2.3 Complex eco systems

So, what is the nature of digital supply chains? The transition from "supply chains to **supply chain networks**" does not mean that relevant activities are now not a flow any more. Neither, it means that, as a result of numerous links and bottlenecks, they would almost be caught up in the "net". Rather, the emphasis on the network idea points to a new pattern of structural design. Complex supply chain network structures are characterized by the fact that they can serve a variety of relations in different ways. For doing so, they are typically partnering on a need-by-need basis in a broader eco system. Ten Hompel (2014, translated) sums it up as follows: "The supply chain network and its nodes must continually adapt to the conditions. Therefore, nodes should be able to move in the future. This prohibits many forms of classic technical infrastructure."

In a nutshell, digital supply chains can be described as complex eco systems, which are enabled by new technology. From a more academic point of view, a more precise **definition of digital supply chain management** can look like the following: Digital supply chain management is a special management approach for highly complex eco systems of object flows, which are based on pattern recognition, generalization as well as self-organization, and leverage on innovative services as well as new technology. Let`s discuss the characteristics in more detail:

The special management approach refers to the **resilient** understanding of supply chain management, its roots and integration focus. Object flows include both goods and information. This is, basically, nothing new for supply chain management. However, considering the so called **digital twins** of a combined virtual and real world such flows are being discussed in a new light and on a new level.

Pattern recognition is the way in which the behaviour of complex systems is being perceived, based on environmental conditions or market requirements. **Generalization** is characterized by comparatively highly differentiated and highly flexible supply chain structures. Such developed supply chain systems offer numerous options to effectively behave in highly complex environments. Generalization does not mean to be quasi "jack of all trades" (or master of none). It can also be expressed to some extent by a multi-specialization. **Self-organization**, then, uses its possibilities by effectively and efficiently linking the subsystems of a supply chain (management). Self-organization is characterized by its recursive, autonomous, redundant, and self-referential attachment (Wehberg 1997).

From a business angle, **innovative services** in this context include both new service levels and new offerings themselves, e.g. analytics as a service for optimizing product performance. Therefore, digital supply chains are a key enabler for new digital business models. For example, an e-commerce platform will not succeed, sustainably, if the order processing is not being performed in a touchless fashion. And for companies that suffer from a lack of qualified staff, automation can be a key growth factor given they cannot recruit the necessary resources in line with their ambitions. In a digital century, supply chain management definitely upgrades towards a competitive factor from a corporate strategy perspective if it hasn't before from a demand driven point of view.

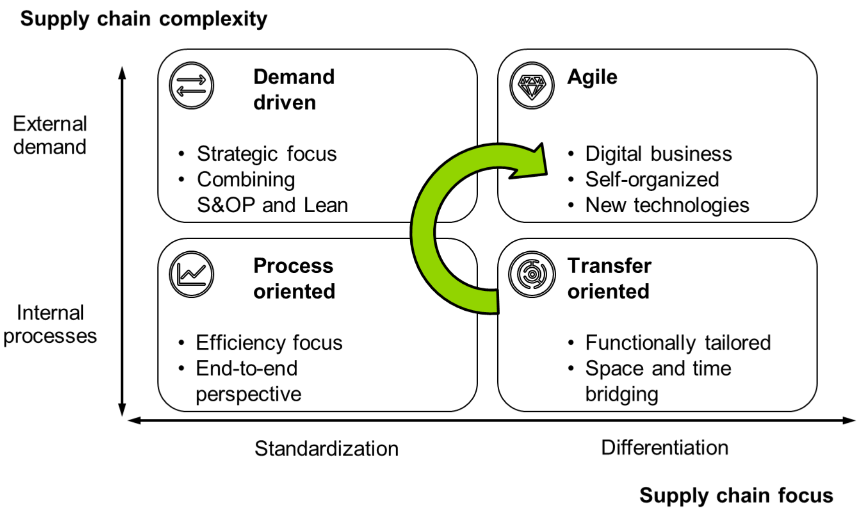
Next to new services and macro-economic benefits, digital supply chains can offer the following **advantages** for companies (Kagermann, 2013):

- individualization of customer wishes,

- flexibility of supply,
- improved resource efficiency.

A summary of the successive understandings of supply chain management and stages of development is given in Figure 2.2. again. In particular, the presentation shows the shift in emphasis from fulfilment execution to strategic impact in the course of its development.

Figure 2.2 Evolution path of supply chain management



Now, what are the key enablers for digital supply chains from a technological and change angle?

2.4 Key enablers: technology and change

As much as a digital twin needs an enabler from a technology point of view, digital supply chains need an IT architecture. Digital twins are enabled by **cyber-physical systems**, which are characterized by the incorporation of computer-aided and mechanical components that communicate via a data infrastructure. In other words, cyberphysics represents the fusion of the virtual and the real world (Broy 2010, Bullinger / Hompel 2007, acatech 2011, Vogel-Heuser 2014).

A suitable **IT architecture** is best represented in three dimensions (according to RAMI 4.0, the reference architecture model Industry 4.0 of Platform 4.0 2015):

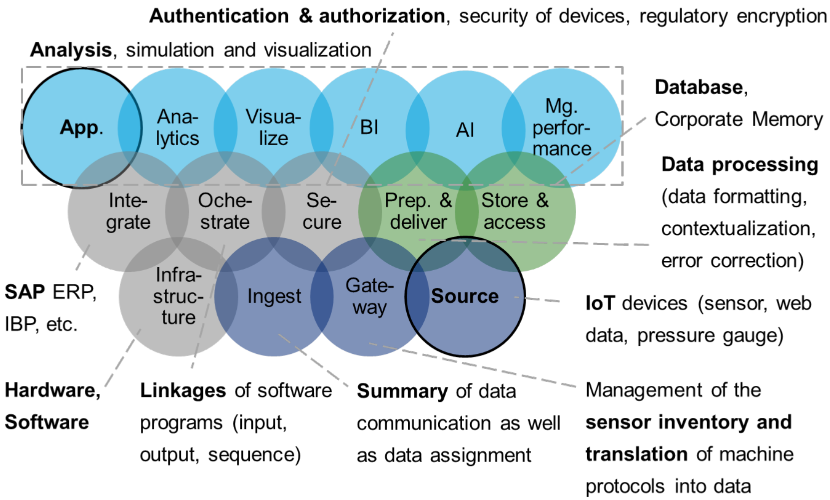
◎ Layers or perspectives,

◎ Life cycle phases and value chains

◎ Responsibilities and hierarchy levels (Figure 2.3).

Regarding different perspectives, established planning and operations software such as SAP IBP, EWM and TMS have to be distinguished from new big data applications. Both are tightly linked with the ERP backbone and its data warehouse, e.g. SAP Hana. Figure 2.3 provides an overview of the different layers of such **big data architecture** for digital supply chains. Interestingly, such architecture can be leveraged for other functions over and beyond supply chain management up to 70 – 80 percent, e.g. for procurement, operations and finance amongst others. In order to connect different things (products, packages, pallets, etc.) it builds on IoT platforms such as Leonardo from SAP, ThingWorx from PTC or Mindsphere from Siemens.

Figure 2.3 Reference architecture for digital supply chains



While the variety of relevant vendors is currently high, established players in-source more and more applications and provide more comprehensive solutions. But even different vendors for the same application, e.g. artificial intelligence, typically provide different benefits today, dependent on the specific use case and its data bases being discussed. This is why it is questionable to choose one strategic partner per application field, rather the leveraging the full potential of vendors on a pay-per-use basis. Conclusively, IT architectures for supply chains are on the move. For example, tracking and tracing focused on locations and could refer to SAP TMS in the past. Digital supply chains track and trace many indicators such as temperature and humidity amongst others. They use aforementioned IoT platforms or even blockchain technology for more extended appliances.

Many companies underestimate the necessity of having an idea of one coherent big data architecture. For learning the technology, they have started to implement some single use cases as a proof of concept. What they don't have, though, is an overall idea how the end-state architecture should look like. They develop proprietary IT solutions for each use case, without having a target picture in mind. Even if they just implement single appliances right now, all these use cases and the future ones will not fit to each other in the mid-term. Instead of building one big **data lake** these companies are dispersing data ponds, which are offering less value, conclusively. For exactly this reason, the motivation to digitalize supply chains can even slow down instead of accelerate. Digitalization in this case takes too long, often does not support competitiveness and fails. A clear idea of the to-be architecture, thus, is a real factor for success, which does not mean that the IT has to be built in one step at once. In line with an agile IT development, it can be build up stepwise as use cases are being implemented. Successful companies are doing it exactly in this way and create momentum for further use cases. They set up a process for use case creation and its implementation, executing dozens or even hundreds of cases a year. This is how a state-of-the-art big data strategy works.

While technology is a key enabler for digital supply chains, other enablers such as **change management** are not less important. The usage of big data technology, for example, can create reluctances of those individuals who use it. Transparency of data facilitates measuring performance of those employees who are generating, using and/or sharing the data. And sharing data means that those humans who are sharing may lose their “monopoly of know how”. Conclusively, using big data technology may be beneficial for the company, however, can feel like a threat to respective individuals, which is contra-productive. Ten Hompel (2014) describes the role that humans play within such digital operating models: "Man is connected to the virtual world via an avatar. This software representative communicates with the social community of the CPS and with the cloud." The benefits of digital supply chains for the individual employee in the company, thus, is an important success factor. Besides use cases, a supply chain manager needs to have a case for change too.

Over and beyond the usage of big data and supply chain analytics associated, change plays a major role for the entire supply chain organization as well as for the IT team supporting it. If you consider the extensive automation potential of supply chains, it is easy to foresee that the need for resources will decrease, significantly, while the demand for new capabilities in terms of digital fluency of the supply chain organization is high. In simply words, a supply chain team will manage those systems in the future that push pallets, rather than pushing pallets themselves. If you want so, supply chain management develops towards a kind of functional CIO organization just because the impact of new technologies as value driver is that high. This evolution challenges the way how supply chain managers are doing their business and can feel like a threat to individuals. Same applies to the IT organization, who was used to deal with ERP systems and infrastructure associated in the past. While cloud solutions make a lot of corporate IT infrastructure obsolete, required skills develop from IT towards OT (Operations Technology).

It becomes clear that a digital supply chain which is state-of-the-art necessarily builds on both a comprehensive understanding of new technologies and its use cases as well as an effective management of change. Having said that, it is important to understand the concept of digital supply chains holistically and not to limit it to selected technologies or change management. Digital supply chains are not possible without cyber-physical solutions. But first of all, it is a business topic. The life of a supply chain manager was always challenging because of the cross-functional role and interdisciplinary competencies required for it. However, in a digital world it, thus, becomes even more challenging.

3 Frame of reference: digital twin of supply chains

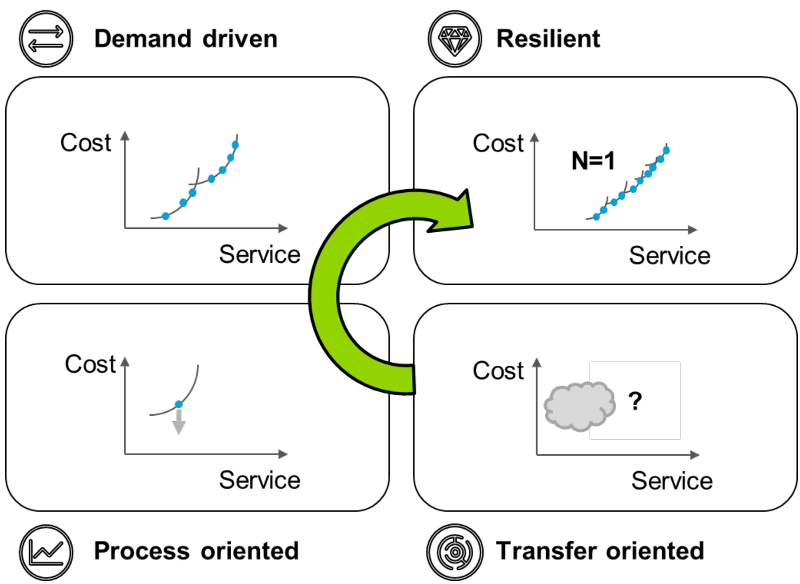
For a sound handling of the numerous tasks and behaviours that are intrinsic to the complexity of supply chains, these are to be brought into a structured order which gives targeted access to specific problems and solutions associated. Although such a **frame of reference** limits the possible observations of the supply chain manager, it is indispensable for his/her orientation (Probst 1981, in general). The value added of such frame of reference results from the sum of its logically permissible statements or recommendations. Having said that, a frame of reference for digital supply chains can be structured with means of the following four dimensions (in the following Wehberg 1994 and 2018):

- Levels of supply chain management, e.g. on a normative and strategic level,
- Systems of supply chain management, e.g. information and controlling,
- Design of the supply chain, with the two poles complexity and stability.
- Digital twin of the supply chain, including interfaces e.g. to product design.

Let us start talking about **management levels**: The task assignments attributable to the complexity of supply chains can essentially be attributed to ensuring their fitness. The **fitness** of supply chains can be described on three levels (Bleicher 1995, Schwaninger 1994): The normative level characterizes its developability, which is derived above all from certain values of its employees and the associated basic attitudes. In doing so, it is responsible in particular for making sense and being meaningful in supply chain management, but also influences the viability of the entire company. Being the key facilitator for digitalization and enabling sustainability of a company are examples for such. At the same time, the normative level sets the framework for opportunities at the strategic level, e.g. by maturing the understanding of supply chain management from a demand driven to a digital one.

Strategic decisions generally aim to create favourable conditions ("to do the right things") for the operative tasks through the effective design of supply chain structures (Drucker 1963). In this context, we want to describe the effectiveness as the quotient between the actual and target cost level and the level of performance of supply chains. It expresses the contribution that supply chain management can make to the competitive potential of the company. In a way, supply chain strategies aim at shifting, segmenting and forming the **cost-service curve** towards a competitive position (Figure 3.1). While supply chain management has to consider all three levels, its strategy is certainly a focus from a digitalization point of view. Many supply chain managers miss the opportunity to contribute to the company`s value from a strategic angle. For example, you just need to ask them whether they sit at the strategy board round table of their company. Most likely not. And many digitalization managers focus too much on technology. They are well integrated within the IT team, however, often less connected to the business. Digital supply chains, however, are the result of doing both addressing the strategic potential as well as approaching it from a business perspective. It redefines the role of the supply chain manager of the future in several regards.

Figure 3.1 Cost-service curve dependent on supply-chain maturity



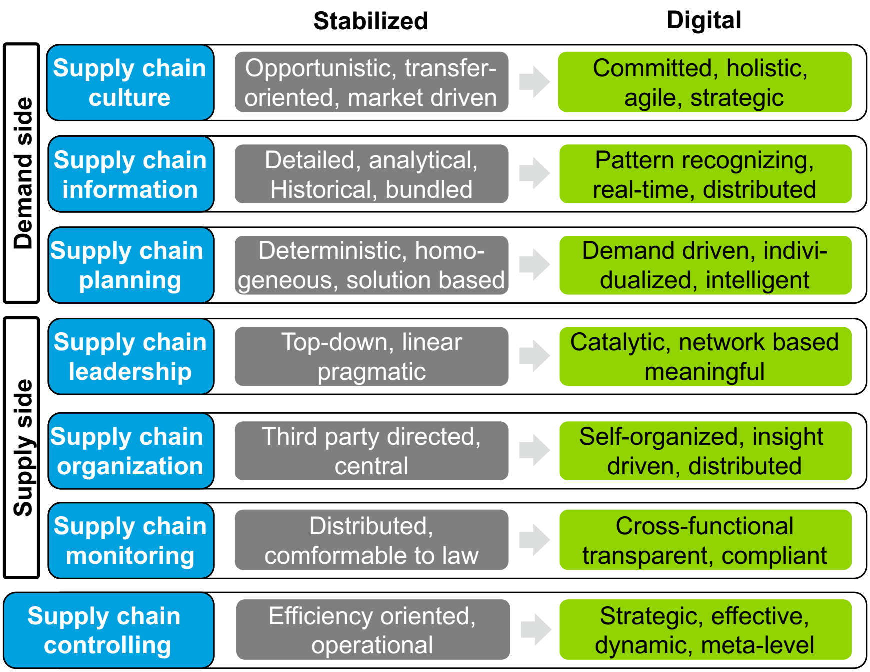
At the heart of the operational level of supply chains is the efficient steering of respective processes ("to do the things right"). The efficiency characterizes the quotient of input and output (Göpfert / Wehberg 1995). It is therefore defined by the ratio of service to costs. With respect to the cost-service curve, supply chain operations want to find the proper position on the existing curve(s) rather than forming a new curve or transforming it. Given a pre-defined design structure and a high degree of automation of digital supply chains, algorithms will cover a huge part of this kind of operations tasks in the future. While the cross-functional coordination of capacities and resources within the S&OP process was characterized by personal interactions in the past, for example, such alignment will be subject to algorithms in the future. In other words, it is not so much about volumes, sites and lot sizes anymore, but about algorithms that determine the right volumes, sites and lot sizes.

Subdividing the **management (sub-) systems**, which is also referred to as hierarchization, leads to a profile system that can be refined to the level of individual design parameters of supply chains (Figure 3.2). Basically, demand side related systems of supply chain management can be distinguished from supply side related ones. The demand side view includes key design parameters like supply chain governance, demand analytics and the planning approach, while the supply side refers to its capabilities, infrastructure and facilitators. Because such a system would be too extensive to be fully explained here, the following will focus on selected system-forming elements of the supply chain values, information and planning in particular.

You may ask yourself, whether the differentiation of the value system of an enterprise through the formation of a subsystem is expedient or not? This can be answered against the background of intelligence. **Intelligence** can be understood as the ability to quickly cope in unfamiliar situations, to grasp the essence of a fact or process quickly and correctly, mental agility, adaptability, curiosity. The ability of rapid thinking and judgment (Schmidt 1974). With regard to the normative fitness level, it should be noted that the presence of subcultures has a supportive effect on the intelligence of the company (similar to Simon 1989). The expansion and maintenance of separate values of supply chain management can be helpful. The significance of the normative also stems from the fact that "with the advent of the fourth industrial revolution (...) the normative area of supply chain management and the operational real-time area of the machines and the physical material flow are decoupled" the (Hompel 2014, translated). A steering is then primarily indirectly, virtually possible via guardrails, which are just above values and standards set.

Now, what about the **supply chain design** in terms of complexity versus stability: The synthesis of the aforementioned St. Gallen management concept and the coordination-oriented controlling approach leads to a reference structure shown again in Figure 3.2. The profile of supply chain controlling represents (graphically) the change (as a measure of complexity) brought about by system coupling. The system forming is represented by all other systems of supply chain management and its change profiles, respectively.

Figure 3.2 Characteristics of digital supply chain management (illustrative)



The amount of change in supply chain management in the course of time ultimately depends on its development. However, it should also influence the latter in favour of the company's objectives. As already mentioned, an in-depth investigation of the development of a supply chain takes place within the fourth part. In particular, we will see what kind of lessons we can learn from relevant academic approaches, if relevant. Given the holistic-evolutionary theory is at the heart of a resilient understanding of supply chain management, let`s see which are relevant design principles that can help. A holistic-evolutionary theory tries to answer the question how much complexity is necessary and how much stability is possible. In other words, it helps to determine the **right degree of change** (as a measure of complexity) dependent on the extrinsic and intrinsic challenges a company is facing.

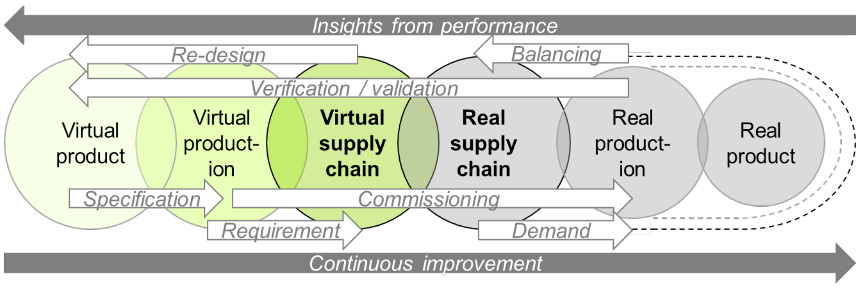
Digital supply chains are not sustainable without an overall consistent design advantage. For this reason, all sub systems have to be designed coherently. Figure 3.2, therefore, shows in a nutshell the characteristics of such holistically understood digital supply chain and its level of change associated. The illustration includes one or the other keyword, so they are to be explained in the following third part. By doing so, the frame of reference determines a clear definition what a complex versus stable design means for key design parameters or systems of supply chain management. This provides a basic orientation and decision support for supply chain managers when developing their operations. At the same time, the target structure will always have to be developed on an enterprise-specific basis. In this sense, the example design of the parameters shown in Figure 3.2 can only be illustrative and directional. There is no digital supply chain "off the shelf", no "one blueprint that fits all". Rather, it is about company and industry-specific solutions. This is especially true in the light of new digital business models. Given that digital supply chains are a key facilitator for such, their design has to be as individual as the digital business model itself. Of course, a discussion about the corporate strategy and new business models associated to a certain extend also refers to common patterns of digitalization.

When it comes to designing **digital supply chains**, today, we do it differently than in the past. We don’t do one-off exercises to determine the network, but we permanently optimize the structure as a result of our predictions in order to balance capacities and material, globally. Our planning is not a closed system anymore, however, dynamically seeks for new disruptions and tries to counterbalance impacts. We even don’t plan ourselves but try to determine intelligent planning algorithms. On the shop floor, we are questioning the traditional MRP logic and introduce demand oriented steering mechanisms. And our supply chain team is not doing physical transport or warehousing anymore but manages automatic transport and warehousing systems. This all is based on a strong and independent supply chain governance that supports self-organization and powerful IT.

To do this on a real-time basis and efficiently, we use standard ERP tools and combine it with new technology. A big data architecture complements the classical ERP as well as supply chain IT landscape and makes use of IoT and AI technologies. Process mining helps to identify the relevant use cases that determine the future architecture. We don’t do big bang waterfalls but develop in an agile way through consistent architecture cuts. IT develops towards OT.

And then we come up with something that we call a **digital twin of the supply chain**. The digital twin is a complex manner and represents a virtual model of the real chain. Typically, the virtual part includes the process, cost-service, geographical and technological parameters. Like in nature, the digital twin allows us to permanently optimize the structure and evolve it over time. Nature is doing many, many things right and optimizes over millions of years and hundreds of generations. The digital twin, however, allows us to optimize supply chains even within hours. Like in the evolution of nature, the digital twin of a supply chain is a digital twin of performance because it supports the feedback loop for a continuous improvement of the network.

Figure 3.3 Digital twin (Wehberg 2018, based on Mrosik 2018)



The digital twin of a supply chain adds up to the digital twin of product design, production and the internet of things (Figure 3.3). In an end-to-end perspective, new products or design adjustments need to have a proper supply chain network. The digital twin thus includes new designs that make, for example, delivery and maintenance easier. It allows us to plan, source, make, deliver and serve in a way that we have never done before. The evolutionary approach of supply chain management creates examples that enhance service levels or flexibility by 60 percent and decrease working capital as well as cost by 40 percent. These examples are very close to nature, which provides fantastic role models for great supply chains.

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Part 3: What a digital supply chain is

1 Cultural aspects

1.1 Supply chain philosophy

Cultural aspects are **soft factors**. And supply chain managers are probably not always used to discuss such, rather hard facts and figures. At the same time, we all agree that soft factors can play a major role for the success of a company and the supply chain management in particular. Therefore, let`s discuss these with means of some guiding questions in the following:

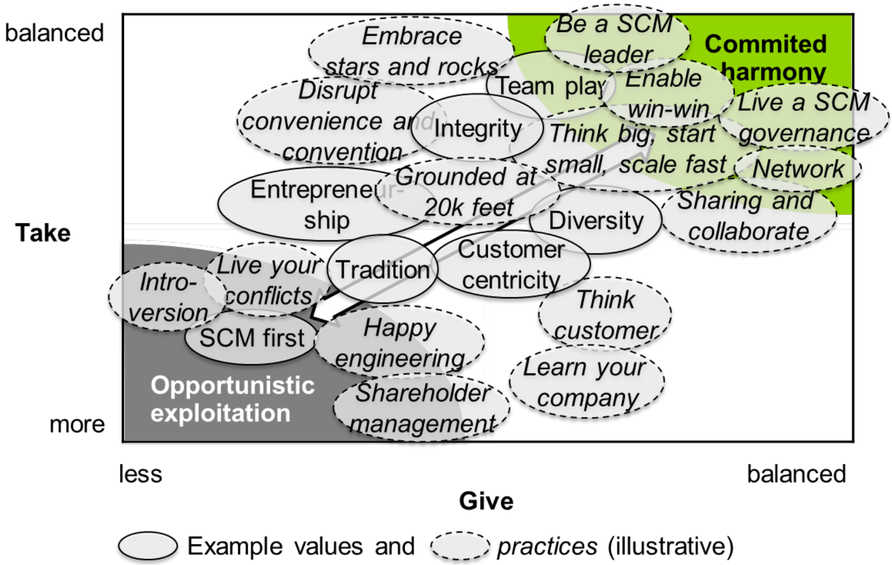
What is a supply chain philosophy? The normative tasks anchored in the supply chain value system deal with the values and the resulting norms, the politics and behavioral culture of related employees (similar to Schmidt 1986). Supply chain values characterize a "conception of the desirable" (Meffert 1992), which is "characteristic of an individual or a group [in the supply chain organization] and which influences the choice of accessible ways, means and goals of action" (Kluckhohn 1962, translated). From the actual stock of the values, which represents the current result of a previous development, the **supply chain philosophy** must be distinguished. It marks a grounding in the intended change in normative supply chain management. Based on basic, paradigmatic assumptions, so-called "basic assumptions" (Schein 1984), it shapes the future development of value. The roots of such assumptions and model ideas go back to the human and world views of a supply chain manager. Since they are usually neither clearly recognizable nor covered, the supply chain philosophy also includes value enhancement, which deals with the disclosure of the nature and content of existing values (Bleicher 1995).

But why does the philosophy play such an important role for a digital supply chain? The importance of the supply chain philosophy for the flow of goods-related management is derived from the fact that the traditional supply chain goals, such as the maximization of the delivery service at certain supply chain costs, due to the increasing system complexity, are becoming insufficient to provide management with guidance. Such a conventional approach alone does not take into account the personal goals of supply chain employees or social claims, although from a systems theory point of view this would be indispensable for a holistic problem solving. For the ability to develop the supply chain as well as the entire enterprise, therefore, the establishment of shared values that provide a sense of supply chain actions is key. Pointing out **meaningfulness**, normative system-building tasks at the same time do have a constitutive effect for all other management subsystems of supply chain management, which means also for its strategic and operational level (Weber / Kummer 1994 and supplementary Bleicher 1992, Weber 1993 and Göpfert 2013).

And how to create meaning or make sense? Meaning can arise, if the relationship of the supply chain management to its environment is interpreted correctly, e.g. by highlighting the need for an increased sustainability, customer friendliness, quality of care or production flexibility. The supply chain philosophy is thus to be understood as a key integration driver. It goes without saying that it requires harmonization with the other elements of the corporate value system. And it can mean that managers first of all acknowledge that they do not not master their highly complex supply chain in a deterministic manner. The concession that "something is not completely under control" can be perceived as very unpleasant and correspondingly difficult, however, has a paradigmatic meaning and is therefore part of the supply chain philosophy. By the way, it shows clear parallels with a shift from an extreme to a "**moderate voluntarism**" in the sense of Kirsch et alias (1979).

Can business ethics help supply chain management? When defining a specific supply chain philosophy, ethical standards can provide assistance. **Ethics** seeks to find systematic justifications for values that grow out of responsibility towards third parties (Jöstingmeier 1994). The essence of considerations of corporate ethics is expressed by the following principle, which is based on the "categorical imperative" of Kant: Treat your counterpart as you would like to be treated yourself (similar to Dyllick 1989). A deeper reflection of this principle leads to the core concern that both the well-being of man and the protection of the natural environment are the objects. In this context, Servatius (1992) speaks of a balanced relationship between taking and giving the company versus nature, thus providing the basis for a supply chain philosophy that is sufficiently committed to ethical principles. For example, a “we first” philosophy does not encourage cooperation because eco system partners might be afraid whether they can rely on their partner and get their fair share or not. On the other side, “sharing” can be a facilitator to liaise, integrate and optimize in a joint fashion (Figure 1.1).

Figure 1.1 Change profile of the supply chain philosophy



The possible significance of the supply chain philosophy as an integration driver is shown in the following example:

Project example: Control philosophy

Initial situation: A mechanical engineering company has successfully grown and internationalized over the decades. On the basis of successful technical developments, the business was set up and expanded in various destination countries in terms of service and sales. Over time, the countries have taken on the P&L responsibility in order to ensure the highest possible degree of decentralized entrepreneurship and customer proximity, despite the considerable size of the company. Functions like sales, service, order processing and supply chain management were owned and performed by countries. Only production, R&D and selected G&A functions (accounting, HR, etc.) were organized transnationally in cost or service centers. The P&L of individual countries served as a control tool.

Objective: The company management had to recognize that efforts to increase efficiency were not progressing because of the de-central control philosophy.

The realization of synergies and any kind of cross-country multiplication of proven solutions was not addressed, comprehensively. While the structures in the countries were often more or less mature, the holistic, transnational perspective did show room for improvement. For example, the company had significantly higher inventories than its competitors because warehousing was conducted at the country level. If one part was missing in Northern Germany, it was reordered and delivered via the headquarters in South Germany instead of asking the warehouse in the Netherlands. And purchasing of transport services did not take account economies of scale. Each country engaged its own freight forwarders and thus contracted sub-critical lot sizes. For this reason, the development of a cross-border control philosophy was decided in order to leverage appropriate synergies and to lead the group to the next level of optimization. A synergetic control philosophy was seen as a precursor to a virtual, network-based organization that enables new technologies. Based on standardized processes the "digital supply chain readiness" was aimed at.

Approach: The initiative was developed and implemented in four steps: First, a blueprint of the future control philosophy was drafted and then refined. The synergistic philosophy of control was not generally advocated, but rather decided separately for each function. Synergies were calculated in the form of global business cases, so that disadvantages were taken into account in individual countries but were not decisive for the further course of action. In the third step, the old and new control philosophy were run in parallel in the form of a pilot, on the one hand to avoid risks, on the other hand to incorporate experience and to secure the acceptance by a successful pilot. The fourth step provided for the area-covering roll-out and the termination of the previous country-dominated control. This was supported by appropriate training and communication.

Result and digital supply chain relevance: As a result of the initiative, efficiency increases of between 7 and 13 percent of the specific cost were achieved for the functional areas concerned. The future viability of the company was also significantly improved by means of now scalable structures. The "digital supply chain readiness" was established.

Success Factors: Crucial for the implementation of the new control philosophy were above all three factors. First, the management of the company had to be convinced of the further development. Especially those managers responsible for the countries were concerned about the loss of influence and a loss of personal power associated. Due to the global business cases and a supporting change management, which took into account MBOs or incentives, this factor was taken into account. Team spirit was strengthened by the definition of a new "win-win" mindset, which required a higher openness and co-operation of executives and employees. Secondly, a transnationally integrated IT landscape was crucial for the efficient implementation of the new philosophy. For this reason, additional IT projects were set up on the basis of the already well-developed infrastructure. This provided a suitable integration platform for making the future control mechanisms happen. Thirdly, it was crucial that the new control philosophy is holistically conceived. In addition to the questions of control parameters and responsibility, the supply chain governance, organization, process landscape and management principles were developed consistently with each other.

1.2 Mindset, openness, orientation and attitude

Practically, the values of supply chain management always result in concrete behavior and vice versa, real behavior forms values over time. This is why actual discussions of such values ideally lead to a challenge of this kind of practical behavior or the determination of desired practices associated. Concrete examples and case studies on how to behave in specific situations are typically more helpful than abstract definitions of values, norms, cultures and so forth. This does not mean that case studies replace such definition, but a pure declaration of the philosophy of the supply chain management is not good enough to implement it, coherently. In the past, you barely find a (supply chain) organization that hasn't defined any kind of short list of its values. If you compare that lists between companies, you will be surprised how much they all look the same. I cannot think of a company that doesn't support team work, for example. But how does the company specifically want the team to work together, when it comes to bottle necks in production or over-promises of sales, and the supply chain team has to coordinate. This is why a practical discussion of **concrete behavior and practices** is key to make supply chain values happen and form one supply chain culture, consistently (again Figure 1.1). Having said that, the desired behavior and values associated can be grouped in four areas (in general Pümpin / Kobi / Wüthrich 1985):

The **goal mindset** reflects the contribution of supply chain management to the harmonization of interests of internal and external addressees of the enterprise. It involves the selection of stakeholder groups for which a benefit foundation is to be created. And it expresses the assessment of the general relationship between the economic goals of supply chains and its social responsibility. Two extreme positions of supply chain practice can be distinguished, the shareholder and the stakeholder approach (Dyllick 1992, Nork 1992, Schaltegger / Sturm 1992 and others):

The idea that the responsibility of supply chain management is reduced to purely economic goals, e.g. the minimization of logistics costs, represents the shareholder approach. Non-economic, such as ecological and social target dimensions are understood in the course of this view only as final constraints. Conclusively, consideration of public concerns is usually limited to compliance with legal requirements. Such an opportunistic extreme of the goal mindset of the supply chain management meets especially with the pursuit of the **shareholders** after short-term realization of success.

However, the consistent policy pursuit in the sense of the shareholder approach, which is essentially limited to interest groups in the task environment of the company, is not sufficient for a higher impact of supply chains by the demands of public stakeholders. Such an increase in concern would be attributable to the fact that certain deficiencies, such as ecological scarcity, are not sufficiently reflected in the market players' behaviour nor by corresponding legal requirements. In such a situation, the supply chain management has to justify the consequences of its action in environmental and social terms. Without the assurance of sufficient social benefits, for example by avoiding traffic jams or packaging waste, supply chain management would question the admissibility of entrepreneurial activity and thus jeopardize the existence of the company. This committed form of a pluralistic orientation of the political logistical goals characterizes the ideal picture of a **stakeholder approach** (Ackoff 1977 and Freemann 1984), in which apart from those interested in the economic services of the supply chain, there are other societal stakeholders.

The entrepreneurial vision, which can certainly be specified for supply chain management (Göpfert 1999), is closely linked to the required goal mindset. In this case, the supply chain vision contains the original idea of what social benefit is to be created, and thus constitutes a kind of guiding star for the supply chain. At the same time, visions are thus reminiscent of scenarios, but differ from them in that they are usually conveyed without an alternative and are based on incomparably more subjective foundations. The formulation of supply chain visions therefore requires a deep understanding of the market and its employees as well as the relevant stakeholders (e.g. Bertodo 1990, Hätscher 1992). To the extent that supply chain management overcomes established contexts of perception, it is also possible to speak of a "transcending vision" (Kirsch 1992). For example, the **vision of a digital supply chain** itself can pave the way for a quantum leap in the improvement of supply chain management and a pioneering role in Germany's successful positioning as a "laboratory for the world". The transcendent nature of such a vision is deliberately provocative and, therefore, encourages employees to think outside the box.

In addition to the vision, the goal mindset of supply chain management depends on the extent to which it meets the concerns of its stakeholders at all, which means especially of its **openness**. The openness of supply chain management describes its internal or external orientation and its ease of change, whereby ideally the following two behavioural poles are typically to be identified (in general Bleicher 1995): The dominance of an inboard structure in the minds of supply chain managers characterizes one end of the openness spectrum, which is called **introversion**. External relations with other corporate divisions, but also with regard to upstream and downstream value creation stages, are not taken into account in the ways of thinking and behaving. As a result of such a cultural pattern, no one within the supply chain really feels responsible for logistically relevant problems of, for example, suppliers, customers and R&D employees. The isolating attitude then leads to the loss of the overall understanding of supply chain services. Added to this is a change-hostile attitude towards supply chains. Suggestions for improvement are reluctant. Corresponding measures are perceived as unpleasant since they disturb the usual "run". As a result, they are only half-hearted. In addition, a corresponding initiative is missing entirely.

On the other side of the openness spectrum, there are externally networked and open ways of thinking and behaving, which are referred to as the **extraversion** of supply chain management. Its high sensitivity ensures that changes in the needs of others are perceived and implemented in their own actions. In this respect, one can speak of an intensively practiced service and total cost thinking of supply chain management towards in-house and external customers as well as against third parties, which concerns both the supply and the disposal side. In addition to the behavioural anchoring of service and cost-related quality aspects, the extrovert culture pattern is expressed in a pronounced employee, customer and competitive thinking on the one hand and social and environmental protection thinking on the other. Essential components of such an open self-conception of supply chains are also thinking in material cycles, which is also referred to as recycling principle (Vester 1980 b), and thinking in flows (Weber / Kummer 1994). The latter is substantiated, for example, by the internalization of the following supply chain principles, which take account of process orientation in the narrower sense (Goldratt 1984, Klaus 1993):

- The production flow, not the capacity has to be adjusted.

- The utilization of a non-bottleneck capacity is not self-determined but predetermined by a different size in the overall process.
- The provided and used capacity is not synonymous.
- A lost hour of the bottleneck is a lost hour of the system.
  An hour gained from a non-bottleneck is comparatively meaningless.
- Bottlenecks determine stocks and run.
- Planning premises must always be checked simultaneously.
- Throughput times are target size, not design parameters.
- Flows are all the more efficient the less "media breaks" in the supply chain occur.
- Flows are all the more efficient the sooner fault prevention instead of retrofitting takes place.
- Flows are all the more effective the higher the match between customer desire, product and process is.

Furthermore, the change-friendly self-image of extrovert supply chain employees promotes the adoption of improvements in the sense of both evolutionary kaizen processes (Imai 1993) and revolutionary innovations. In contrast to the rather opportunistic introversion, extroverted thinking and behaviour are better prepared to promote the affirmation of dynamism and complexity. For this reason, they are to a certain extent also a prerequisite for the implementation of digital supply chains and change-oriented management structures per se. In the context of digitalization, openness also means that the relevant technologies can communicate with each other and ensure data continuity (Vogel Heuser 2014, Büttner, 2014).

In addition to openness, the **temporal orientation** of supply chain management also influences the orientation of general, political goals. The temporal orientation describes its position on a spectrum between past and future imprinting (in general Bleicher 1994): The history of the past is attributed to supply chain employees who look back on the successes and laws of the past. By doing so, they seek for security. In this respect, the cultural image is characterized by a "**spiritual gilding of the past**", thus reflecting a rather lethargic, opportunistic attitude. Instead of the possible, what has been made, instead of performance, it focuses on the status quo of the so-called "old hands" of supply chain management, which invoke their wealth of experience. However, it is overlooked that past experience in complex supply chain systems often does not provide much assistance. In such situations, it is less the "monolithic traditionalist with the completed life experience [who is in demand and] who blocks the offspring with his own pioneer past, [...] but the flexible partner whose projections are convincing" (Höhler 1992, translated). This is especially true for the implementation of the concept of a digital supply chain. Despite the danger potentials above, however, moments shaped by the past will always play a role in the minds of managers. Among other things, the supply chain culture is the product of the company's development so far.

In contrast to the past-oriented image of the culture, the **future mood** reflects a pattern of behavior characterized by the fact that supply chain managers commit themselves to possible rules of the future, by anticipating them, by influencing them by correspondingly innovative means or by robust steps (Haussmann 1978). The great importance of shaping the future and focusing on innovation in particular results from the fact that with high complexity, only an excess of behavioral offers provides the necessary mental flexibility in the minds of supply chain employees. More of the possible over the real promotes the creativity of supply chain management and is also the source of innovation (Höhler 1992). In this sense, digital supply chain management always means innovation and requires shaping the future.

Despite the opportunities that come along with an innovation-oriented attitude of thought, the future imprint of supply chains can certainly also open up danger areas. The loss of tradition associated with an over-emphasis on future changes can lead to severe culture irritation. It can lead to uncertainty among supply chain employees in the performance of strategic and operational tasks. Orientation standards are missing when old thinking patterns are adopted, but new ones are not yet established. In addition, the development momentum that has now been perceived can make supply chain management feel tempo-pressure and therefore eliminate the need for stakeholder involvement in the decision-making process. The exaggerated shaping of the future then leads to an impairment of the openness of supply chain management and thus jeopardizes its ability to develop (Höhler 1992).

Since every political goal-setting process requires a normative framework, the **attitude of conflict resolution** is a central constitutional value of supply chain management. The possible conflict solution modes can also be removed on a spectrum (in general Bleicher, 1995): On the one hand, supply chain management can tend to have regulations which unilaterally represent the interests of only one reference group. In this case, the responsible supply chain managers tend to uncompromisingly enforce the alleged "corporate interest", if necessary also through appropriate tactical and opportunistic behaviour. Such a form of conflict resolution, however, permanently discredits the trust of supply chain management, which is needed to fulfil its interdepartmental coordination function and the associated relationship maintenance. This creates at the same time unfavourable conditions for the realization of strategic and operative tasks. Such a conflict-promoting framework is therefore called **confrontation**.

As part of a conflict-resolution mode counterbalancing confrontation, supply chain management is committed to finding a balance between the pluralistic interests in accordance with its cross-sectional function. Other areas as well as subordinate employees are given a say. This type of conflict prevention is called **consensus building**. As part of a collaborative dialogue, a consensus will then be found between the various in-house and external stakeholders. The path of consensus thus takes into account the requirements of a future-oriented and open supply chain culture, insofar as it does not lead to the uncertainty of the excluded and thus contributes to the fact that changes are not perceived as a threat. (Kanter 1993) For this reason, consensus building also fits in with the network character of digital supply chains.

Realistically, supply chain management will always have to position itself between confrontation on the one hand and consensus building on the other. For one thing, conflicts resulting from diverging interests of supply chain managers towards its stakeholders can never be completely ruled out. On the other hand, they can be regarded as a performance-enhancing factor for supply chains up to a critical level. Functional consequences arise when ideas are stimulated, tensions are relaxed, clear relationships are created or one's own positions are reconsidered (Kast / Rosenzweig 1985, Nork 1992).

The profiling of supply chain management on the basis of the above-mentioned normative, soft factors is often given too little consideration in practice. To take care that such soft factors in the sense of a "**change management**" are consistent, can be the crucial success factor.

The change profiles relating to the mindset, openness, orientation and attitude of supply chain management suggest a distinction can be made between a rather **stability-oriented-opportunistic** and change-oriented-obligated system formation. The former results in a past-oriented and introverted supply chain culture; it corresponds to the shareholder approach and a confrontational conflict resolution mode. The supply chain management is so far barely able to represent (in a given period of time a large number of) various interests, to take into account the rules of the future, to perceive changes in the needs, etc. The resulting level of complexity of the normative management level of the supply chain system is correspondingly low. Otherwise, the latter, the **change-oriented system formation**, implies a high degree of system complexity of the normative.

The supply chain (meta-) management has to establish a fit among the elements of the supply chain culture as well as between this and its other over- and subordinate systems. The redefinition of the supply chain philosophy, which is relevant in this context, may well be understood pragmatically in the sense of a "**culture follows strategy**". It forms a necessary condition for the development and maintenance of success potential through strategic supply chain management, which will be explained below. The situation analysis of the information system forms the starting point for the strategic planning of supply chains.

2 Supply chain information

The supply chain information system identifies a structured set of all activities for provision of information, especially for the collection and evaluation of information about the current events of goods flow relevant facts. Since the information system is part of the management system, the other executive subsystems, such as organization, planning and control, are the **addressees** of the information system. Information can be interpreted as knowledge needed for the primary coordination of its addressees. In addition to this customary definition of information in the sense of "**purposeful knowledge**" (Wittmann 1959), Weber and Kummer add experience to the scope of the information system. In this way they address a rather undirected broadening of the knowledge base of a supply chain, which, however, is by no means to be confused with the production of so-called numerical cemeteries, but rather refers to the determination of adaptation constraints and innovative possibilities of supply chain management (Weber / Kummer 1994). The latter understanding is very relevant in connection with the possibilities offered by digital supply chains. It also shows that collecting huge amounts of information, which is also called **big data**, and comprehensive data storage facilities associated, also called **data lakes**, do not necessarily provide value per se, however, need use cases and specific direction to generate value. But let`s start at the very beginning. What is new about supply chain information in an increasingly complex environment?

2.1 Complexity, information and coordination

As already mentioned in the introductory part, the complete recording of all information relevant to flow of goods in highly complex contexts and digital supply chains in particular is not possible. Strategic tasks of supply chain management are influenced by high dynamics of external influencing factors in addition to the complexity resulting from the cross-sectional function of supply chain management. Therefore, strategic tasks in particular are characterized by high **uncertainty**. In addition, a number of operational tasks is challenged by disruptors, in the meanwhile, which means by factors that have not completely been anticipated. For example, disruptors question the traditional MRP planning for make-to-order supply chains. Consequently, the **controllability** of such strategic and operational issues is limited.

From an information theory perspective, the relationship between the complexity and coordination of a supply chain is as follows (in particular Malik 1993): The work of Ashby (1965, 1970 and 1971) and Conant (1968) on information transmission has shown that any coordination of a well-defined fact requires a certain minimum amount of information. Without the transmission of this minimum amount of information, therefore, the solution of a coordination problem is not possible. The **transmission capacity** thus becomes a measure of the coordination capability. The required transmission capacity depends on both the complexity of the data input and the output. Take the example of a transmission model composed of m transmitter variables X and n receiver variables Y as well as an information system F transforming the input into an output. If p is the number of all possible input states and q is the number of all possible output states, p = q = 21000 results for every 1000 binary input and output variables. The number of all transmissions, the p input in q output conditions, is then qp. It requires a minimum transmission capacity of the information system of about 10300 bits. It becomes clear that the required transformation capacity of the information system is primarily determined by the **input-side complexity**, which represents p.

On the other hand, **Bremermann** (1962 and 1965) demonstrates on the basis of findings from quantum physics that a system consisting of matter can process information only up to a certain limit. He concludes that this is a maximum of mc2 / h [bit / sec]. is, with m = mass of the system, c = speed of light and h = Planck's constant. The formula leads to a top limit of the physically possible information processing in the amount of 2 * 1047 bit / g / sec., which is also called Bremermann's limit.

In this context, **Malik** notes that although the Bremermann limit seems very large, it is actually very small when it comes to capturing really complex systems. For example, in the forefront of strategic supply chain planning, which includes n binary design variables, is more complete interaction of the elements of the considered system 2n possible states to capture. If, for example, one assumes that there are 7 goods groups in a supply chain division that can be distributed in 6 countries to 3 target groups, each with 3 different service levels, supply chain management has to take into account 378 variables and thus 10113 options. Although it may be objectionable that certain options can already be ignored in the run-up to supply chain planning because they are obviously leaving. However, the elimination of certain opportunities must first be taken and is associated with a certain amount of information. In addition, the acquisition problem becomes significantly more extensive if one considers that the supply chain area mentioned also relates to other branches of the company. In particular, the coordination tasks of supply chain management require amounts of information that are often no longer representable in the light of Bremermann's limit. As a rule, the amounts of information to be included are at least so great that the design of the information system is of eminent importance. However, this situation, that is, the link between limited transmission capacity and limited coordination, does not seem to be well-known to many executives and even less conscious. The inadequate consideration of these information-theoretical laws thus leads to a more "**arbitrary choice**" of a more or less plausible strategy from a very large number of equally possible alternatives. It "resembles a drive through a ramified river delta, although one is unaware that one is even in a delta." (Malik 1993, translated) And it is equivalent to the denial of system complexity.

Against the background of the above information-theoretical basics, it becomes clear on the one hand why it is often not possible to completely capture all goods flow-relevant detailed information. On the other hand, it can be seen that the lever for an adequate design of the information system is on the data input side. Instead of the detailed depiction of all goods-flow-related facts, the **recognition of patterns** should occur. This means capturing the order of the system under consideration. Unlike in the above example to the planning problem of said supply chain division, it can be assumed that in reality there is usually no complete interaction. With other words, even in complex systems, "not everything is connected to everything on a regular basis, but just 'a lot with a lot'. However, this statement must not give rise to the assumption that the Bremermann limit just explained would not be relevant. In addition to this quantitative aspect, qualitative features of system complexity seem to be of particular interest. It raises the question of how or how much is connected with much. The order thus contains rules resulting from the interplay of behaviours and processes within the supply chain and surrounding system. It favours and constrains certain behaviours of the system, expressing what makes up the system as a whole and, at the same time, allowing us to grasp system complexity. Here, order can be understood both statically in the form of a combination of substructures to a whole as well as dynamically in the sense of a certain system behaviour over time. Above all, the relatively young interdisciplinary science of **Synergetics** (Haken / Haken-Krell 1989) deals with the recognition of dynamic states of order. All in all, pattern recognition becomes the prerequisite for coping with complexity (for this and in the following Ulrich / Probst 1991 and Weick 1969). It is the core component of digital supply chains. And it is capable of closing the already mentioned so-called "knowing-seeing-gap".

Using the example of a **football** game, which also represents a highly complex system, pattern recognition is particularly evident in the perception of rules and tactical moves. A detailed analysis, such as a slow motion of a shot on goal, here contributes little to the understanding of the game as a whole. Even if the comparison between a football game and a supply chain may be considered conditionally permissible - the rules of football are still widespread - it does illustrate what is important in pattern recognition. The supply chain manager, who sees himself as a sports layman with ever new disciplines, has to familiarize himself with the changing rules of the system. Patterns of supply chain systems can be expressed, for example, by the ordering behaviour of customers, in order changes, delivery service requirements, ecology damage or load levels of transport capacities.

The fact that complex supply chains can only be modelled and not analysed in detail may lead one to conclude that, since "everything is so complex," there are no **deterministic statements** about how the system operates possible and therefore it is no longer manageable. In this connection, Hayek distinguishes two types of deterministic statements: Thus, this statement can mean "which class of circumstances determine a particular kind of phenomena, without us determining the individual circumstances that decide which Individual case from the predicted class of patterns will be able to specify individually. Therefore, we can justifiably claim that a particular phenomenon is determined by known [... forces] and at the same time admit that we do not know exactly how it came about. Further, asserting that we can explain the principle that a particular mechanism works invalidate the fact that we are not able to say exactly what it will produce at a particular space-time." (Hayek 1972, translated) Thus, even in complex systems of supply chains deterministic statements are possible - in the sense of Hayek.

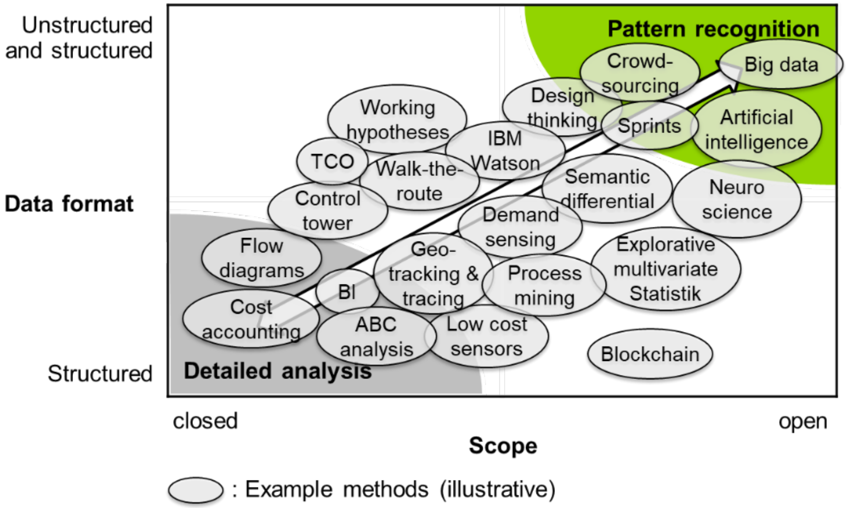
2.2 Pattern recognition

By focusing on strategically relevant information, the level of complexity to be captured increases relative to information required for the operative business (Scholz 1987). In the course of forming the information system for strategic supply chain management, it is therefore more important to prioritize information instruments and methods that take into account the pattern recognition process. In this context, we can describe the spectrum characterizing supply chains between pattern recognition and detailed analysis in particular by two dimensions, the **scope and format of data** (Figure 2.1):

The data volume or information content expresses the extent to which the way of information collection is closed or open. The closed procedure means that the data is collected according to predetermined criteria and obtained from known sources. Such information retrieval often corresponds to "hard" data, which means with a high degree of data in quantitative form. The problem to be mapped here is relatively well structured and can therefore be detected relatively well in its quantity and value framework. Although quantitative closed-loop data often promise information-economic advantages, in the majority of cases such data are history-oriented and therefore at best allow for an unobjectionable extrapolation of the past. Their information content is comparably low. They characterize the detailed analysis in the form of a **stability-oriented information system**. For the number and variety of data that can be processed in such systems (in a given period of time), so the complexity of the information system of a supply chain, is weak. Examples of these kind of information systems are traditional business intelligence (BI), total cost of ownership (TCO), ABC analyses and confirmative statistics amongst others.

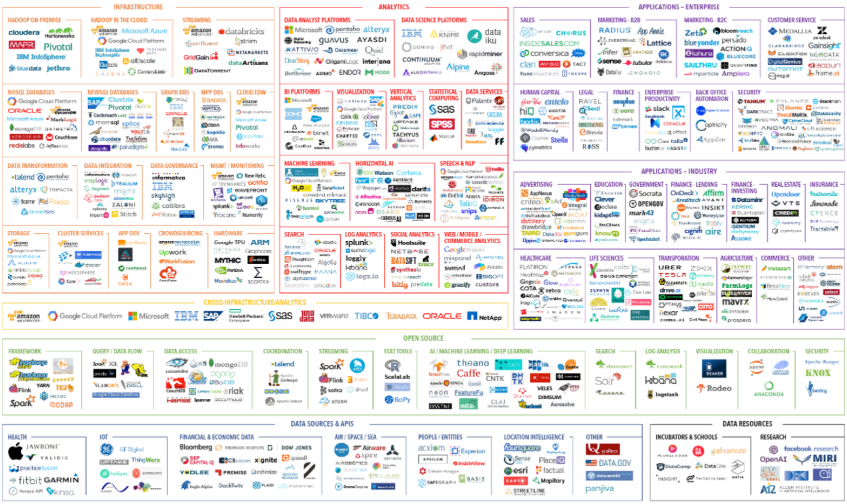
Qualitative-open information is contrary to the quantitative-closed and therefore the detailed analysis. They result from the freedom of the information system to consciously absorb new sources and data, are more prospective and, above all, take account of pattern recognition and the already mentioned need to advance the accumulation of experience for supply chain management. Your information content is high. The qualitative character that characterizes them is expressed in particular by the consideration of so-called theoretical constructs, such as customer satisfaction, which can either be measured multidimensionally by indicators, recorded as semantic differential or verbally described (Borkowsky 1994 and Mann 1995). Qualification therefore does not exclude the use of quantitative data. The openness or scope of the information recording is also reflected in this context by the involvement of the later affected persons, who can ensure both the use of the entire know-how available in a company as well as the acceptance of the acquired data (Weber / Kummer 1994). In addition, this approach most likely promises to capture the essential features of a complex supply chain. In this respect, it describes a **change-oriented information system**. Example methods or tools that represent such kind of information systems are design thinking, sprints, crowd sourcing and artificial intelligence amongst others. With respect to design thinking, a number of different interpretations of that method exist in the meanwhile so that it is worthwhile taking a closer look. Well known in this context is also IBM Watson, which is traditionally focusing on unstructured data, i.e. text, and thus can be a good complement in a change-oriented information system.

Figure 2.1 Change profile of supply chain information



In addition to the variables explained here, it goes without saying that further characteristics for the description of the information system can be mentioned. For example, the **relevance of the information** for the decisions of supply chain management is of high importance, which suggests that useful information and not "data cemeteries" are provided. Further, not insignificant requirements also form the **objectivity** of the acquired data, their **profitability**, **reliability**, **validity** and **completeness**. However, the above features of data form and scope express, in particular, the ability of an information system to capture the complexity of supply chain-related variables. In addition to an allocation of the information system as a whole, individual instruments or tools, such as flowcharts and ABC analyses, can be positioned in the change profile shown in Figure 2.1.

Figure 2.2 Vendor portfolio for big data (selection by Turck et al. 2017)



In practice, many companies are currently developing their portfolio of information tools in order to support their digitalization strategy and leverage the value of data. The **lessons learned** of such exercises suggest that typically the tool selection has to be performed in a use case specific mode. The traditional way of selecting tools suggests one preferred vendor per field of appliance, e.g. for artificial intelligence tools. However, this does not leverage the full potential of such tools. Even within one appliance field the tools differ and show individual strengths or weaknesses dependent on the single use case to be analysed. A **multi-vendor strategy** thus has to refer to a pay-per-use based subscription model rather than time-based licences. Figure 2.2 provides an overview of the vendor portfolio in 2017, which includes an increasing number and evolves dynamically over the years. The figure may be too small to read every vendor, which does not really matter. It just should give an impression about the multitude of tool offerings in this context and how large the vendor portfolio is.

Moreover, the scope of relevant information shifts from G&A functions towards operations, in other words **from IT to OT**. And many IT organisations are not very experienced with the latter. This means they really have to set up in a cross-functional fashion to secure sufficient supply chain as well as IT competencies appropriately. The set-up of a supply chain information system necessarily is interdisciplinary.

2.3 Big data, predictive analytics and sensors

In supply chain management practice, the need for pattern recognition has already had many effects. This development is supported by the improved technological possibilities in three ways:

Firstly, the digital **storage and processing capability** of large data volumes has become possible and has been growing strongly since the year 2000, which is where the expression "big data" comes from (Hilbert, Lopez 2011). The processing of large amounts of data has long been possible via mainframe computers, but in recent years also on smaller computer capacities, in some cases virtually via cloud computing and, from an economic point of view, very economically. The data volumes, which from a supply chain point of view can be relevant here, basically refer to process-related data, customer data, supplier data, but also employee data and data of other stakeholders or environmental sources. They require a certain degree of accuracy, for example in the minute range for just-in-time delivery, which in turn drives the data volume.

Having said that, it is not alone the volume of data that can be stored, but also the opportunity of bringing the data together and understanding how they relate to each other. Particularly, the combination of relevant data can create value just because it allows to identify and understand the underlying drivers of value drivers. As a prerequisite, the relevant data base has to be integrated, which means there is a technological platform that enables combined analyses. This platform is called **data lake**. The data lake ideally grows over time, as the supply chain management learns about big data and progresses in digitalizing its supply chain. Ideally, more and more use case are being implemented, data assets integrated and value generated along the journey towards a digital supply chain.

Secondly, the improved and more economical capacity of computing power has significantly improved the ability of **predictive data analytics**. These new possibilities of data analytics are the core of any pattern recognition process insofar as the intelligence of corresponding algorithms decisively determines the quality of identified patterns and design recommendations to be derived. Such algorithms are procedural instructions that allow a decentralization of decisions. Ten Hompel (2013, translated) says insofar: "We can give the machines a bit of thinking - but shall keep the plug in our hands." Next to artificial intelligence, multivariate analysis methods of statistics such as factor, variance, cluster and other analyses as well as simulations with incremental improvements (Bousonville 2009 speaks of evolutionary algorithms) can help to identify and apply corresponding behaviours of supply chains.

Modern IT tools for the field of predictive analysis are already able to comprehensively support the supply chain management, in particular to perform:

- Demand forecasts,
- Environmental analyzes of traffic jams, pollution, etc.,
- Social media and market research,
- Customer relationship management,
- Data management and validation,
- Improvements to the product and service portfolio,
- Network planning and optimization, including transport routing,
- Resource and capacity management,
- Crowd logistics,
- Compliance management,
- Assessment of supply chain risks,
- Financial and investment planning.

Decisive for the beneficial use of such IT tools are, above all, the selection of the right **algorithms**, the availability of relevant data and sufficient expertise in the supply chain context. Some marketing initiatives try to give the impression that there is a salutary algorithm that can solve all problems. Experience has shown, however, that in the field of probability analyses, a large number of algorithms are typically available for one and the same type of analysis. And again, it is not about the comprehensive consideration of as much data as possible, but about the integration of the relevant sources. Particularly relevant are those data that potentially serve as a determinant (underlying driver) of a target variable, such as capacity utilization, delivery flexibility or throughput time. Not least for this reason, it is also necessary, in addition to a sufficient analytical expertise, to integrate sufficient supply chain expertise.

While in the US auction platforms already exist for the development of the best algorithms, this market in Europe is still in the process of being developed. It should also be assumed that such algorithms require certification, which means quality assurance by third parties. In addition to the development of algorithms for the operational steering of object flows, algorithms for the design and development of supply chain systems as a whole will play an increasing role. Since the latter relate to the coordination of supply chain management and are closely linked to controlling tasks, we can also speak of **meta-algorithms** here. They take care for the development and selection of the right algorithms. Bauernhansl (2014) speaks similarly in this context of "system of systems", which refers to the autonomous development and design using the plug-and-produce capabilities of systems.

Thirdly, the decentralized use of IT in supply chains also benefits from the reduced storage capacity in combination with significantly more economically viable use of **sensors**. This trend enables the decentralized control of the smallest units, e.g. of transport means, packaging, industrial trucks, etc. Cost-effective sensors are usually seen in concert with other technologies, such as the mobile and wearable computing. Their potential use in supply chains is broad and can for example (Kückelhaus et al., 2013):

- influence user behavior on a personal and business level
- integrate customers as an active partner in the order process,
- promote the use of Auto-ID technologies in businesses and customers,
- improve personal work through the use of wearables,
- support the BYOD trend (Bring Your Own Device),
- provide a man-machine interface for (self-) control,
- enable the smooth actual-time tracking of shipments and
- make a corresponding control of supply chains possible

The different sensor types can be directly assigned to the "6-R" of supply chain management, e.g. in the right place with GPS / WLAN / GSM cell, in the right quality with temperature sensor / depth image scanner, etc. Additionally, there are also actors who do not measure, but perform certain actions in a decentral fashion and automatically.

The rapid technical development of sensor technology is mainly to be described in three dimensions (Tuttle 2015):

- **Energy efficiency**: The energy consumption of the sensors is very low, e.g. in the lower microampere area of button cells. It will continue to reduce even further in the future in order to be able to integrate even more functions per sensor.
- **Connectivity**: The sensors are characterized by different connection technologies, such as WiFi, Bluetooth, ZigBee, Thread amongst others. Each technology is characterized by its own strengths and weaknesses, such as range, IP capability, energy efficiency and network capability.
- **Integration**: Sensors combine numerous functions, such as memory, processor, receiver, energy management, etc.

Of course, the combination of the three approaches mentioned, big data, data analytics and sensors (or cyberphysics), offer corresponding possibilities for pattern recognition in supply chain management.

2.4 Master data and contextualization

In the context of the perception of complexity, a distinction should be made between endogenous and exogenous complexity. In other words, there is home-made and external (ly determined) complexity. In practice, **home-made complexity** often arises from master data that is not consolidated and unified. For example, the bill of materials and customer data are heterogeneously structured and documented due to external growth in the past. And the parts lists in the various functional areas (procurement, production, etc.) and sites differ, like the material number in SAP. This unnecessarily creates additional complexity and downsides. For example, different material numbers at different sites make it difficult to balance both capacities as well as material. Home-made complexity can be countered by consolidating master data management, **cleansing** master data and streamlining the portfolio of products, parts, production assets, customers and suppliers. Ideally, companies start such data cleansing activities while working on their supply chain of the future. Otherwise, they risk to approach digitalization too late from a market and competitive perspective.

Next to cleansing, modern big data architectures suggest that the **contextualization** of data helps to make such data comparable and to consolidate. Of course, contextualization only helps to harmonize nomenclature, while data cleansing addresses redundant and wrong data. If the data are cleansed, however, contextualization is a pragmatic way to consolidate different sources in a meaningful way, rather than developing data lakes as one source of truth over years. Data lakes are relatively easy to implement if they are close to the ERP landscape, like in the SAP Hana environment. However, in the operations sphere and all its different systems, a contextualization approach often is more realistic today. This may change over time, given that existing IoT platforms in operations and supply chain management in particular all strive for standardizing use cases and consolidating data associated.

Many companies also do not adequately assess the complexity of their offering portfolio and related costs or contribution margins. The current portfolio thus is not questioned. To what extent individual products are profitable, is not well-known, because the cost calculation offers no information about it. The allocation of cost (via cost centers) to products and service providers is not realistically represented by an appropriate cost driver logic. Instead, important information is lost through averaging. Understanding actual supply chain cost via **de-averaging** and based on relevant cost drivers is therefore a prerequisite for determining the right degree of complexity in a commercially viable fashion.

The consolidation of the product and parts portfolio also requires integrating of the **bill of materials** of various functional areas. Moreover, the development of **configurable products** through standardization, parameterization and modularization allows flexibility at the same (or lower) cost. Appropriate IT support through suitable software solutions and using classification standards such as eCl@ss or others is the basis for a consistent management of the material management data in this case.

Efficient handling of internal complexity is anything but trivial in praxis. The following use case shows which types of material management can be used here. They are the prerequisite for the effective examination of external challenges and digital supply chains in particular:

Project example: Integrated materials management

Initial situation: A FMCG company has significantly broadened its product range over the years. Due to an increasingly individualized consumer behavior, it has also differentiated the product range in order to maintain its competitiveness. An as-is assessment showed that the contribution margins of the various products were extremely different and partly negative when taking total cost into account. Incidentally, the number of products offered was simply out of control, which was illustrated by a comparison with selected competitors. Also, at the level of semi-finished products and raw materials, there was a very high level of complexity. In many cases, the introduction of new stock / shelf keeping units equaled the introduction of new inventory.

Objective: In order to re-organize the complexity of the offering portfolio, the company set up a program. The aim was to consolidate the supply ("above the skin") by streamlining the portfolio. On the other hand, the semi-finished products and raw materials ("below the skin") should also be studied to more efficiently manage, as far as possible, the complexity within the production and supply chain. On the basis of common classification standards, integrated bill of materials concepts should be implemented, which are equally taken into account in procurement, production and distribution.

Approach: The program was executed in four steps. In the first step, the complexity costs and corresponding complexity and value drivers were determined. The complexity drivers were not limited to the actual product performance, but also included secondary services such as special packaging and shelf maintenance. The analysis of contribution margins taking into account the complexity costs revealed potential for improvement in the supply portfolio. The analysis of the complexity drivers showed possibilities to develop integrated parts lists. In the second step, the products were prioritized appropriately. The focus was on the current contribution to success and the identifiable potential for improvement. On this basis, pilots were set up for an effective materials management in the third step. The relevant measures were very comprehensive because they took into account both complexity-reducing and value-adding starting points. The task of the pilots was to demonstrate the feasibility of the methodology and generate momentum for further implementation. At the same time, work was carried out on processes for the permanent anchoring of future materials management. The implementation of the latter together with a company-wide rollout were the subject of the fourth step.

Result and digital supply chain relevance: As a result of the program, the pilot product range could be reduced by more than 20 percent and the value could be increased by similar price measures. This laid the basis for a successful rollout over the other product areas with a potential of comparable magnitude. In addition, the defined processes of the improved materials management, for example for pricing and customer segmentation, can be implemented in a self-controlled manner in the sense of a digital supply chain.

Success factors: Three factors were decisive for the successful implementation of the material-efficiency program. Firstly, it was important to recognize that not only comprehensive complexity reduction can be the goal. In intensive discussions with the executives of the company, it became clear that the company is currently living on the complexity of its customer requirements and that responding to individualized customer requests through new offerings is a core competence. In many cases, therefore, it had to be about paying the higher complexity appropriately. Secondly, it was crucial for the acceptance and effectiveness of the program not to limit itself to product articles, but also to scrutinize the corresponding semi-finished products and raw materials. As a result, the discussion has been extended from the level of portfolio management to the bill of materials level. In other words, not only the "what" was at stake, but also the "how". Thirdly, it was important to manage the expectations of those involved realistically. The further development of BOMs is usually a medium to long-term endeavor, so that the program aimed in many areas at anchoring suitable processes instead of the future BOM itself. Over and beyond quick wins on product portfolio level, a continuous improvement process has been initiated, accordingly.

3 Supply chain planning

3.1 Target setting

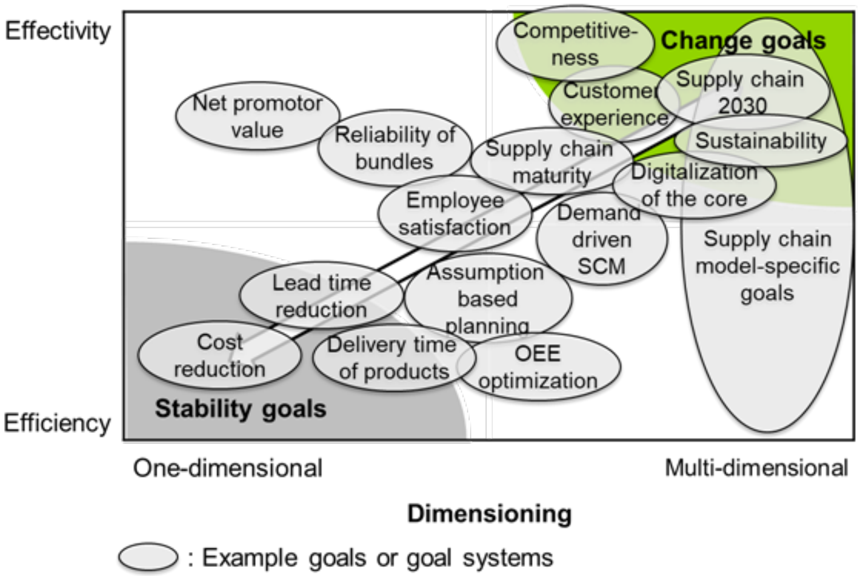
Supply chain planning is a process of qualitative, quantitative and temporal determination of future goals, means and [...] processes for the design and control of the operational supply chain management system, including systematic, information-processing [...] and social interaction processes" (Bircher 1989, translated). In a sense, a crystallization point of all planning activities is the target system. It is the result of strategic and tactical, rather than operational supply chain planning. And it is always an integral part of the target system of the company. The effort spent on the target setting of supply chain management compared to other divisions is derived from its attractiveness (Weber / Kummer 1994). In a resilient perspective, the target system of digital supply chain has to be structured as follows.

The change of supply chains that is expressed by the target system can essentially be determined on the basis of its dimensioning and target level (Figure 3.1). As already explained, supply chain problems are usually characterized by multi-dimensions, which means they are defined with respect to their economic, technological, environmental and social implications. Companies, which in extreme cases limit themselves to only one, usually the economic dimension, disregard the high dynamics that can arise precisely from the other dimensions. Such a comparatively isolating approach tends to be accompanied by a focus on efficiency standards. Supply chain costs are then often used as input for measuring efficiency. In addition to the monetary costs, delivery time can be understood as an input variable. It leads to a time-based efficiency measurement (Jacoby 1994 and Pfohl 1994). Efficiency is to be ascribed to operational supply chain management as it directs supply chain processes in existing structures and tries to optimally position itself, graphically speaking, on a given cost-service-level function. It thus primarily pursues **stability goals** that represent stability-oriented structural patterns of the supply chain target system.

The challenge of stability goals and its efficiency-focus is that due to the missing multi-dimensioned approach these goals often lack differentiation and connectivity to demand patterns. For example, so called Runners are characterized by stable demand and high volumes opposed to Noisers, which include rush orders and highly customized products. The consideration of **supply chain models** and thus a differentiated steering logic is missing. In this case generic goals suggest that all products can follow the same logic and the supply chain can be managed as one, typically via demand forecasts and respective inventories. This ignores, however, that typically the demand of Noisers are hard to forecast and that the management of the supply chain seeks for differentiation. Supply chain goals, therefore, need to consider these changes in a complex world.

The stability goals are opposed by **change goals**. On the basis of their multi-dimensional facility, they address the dynamization of the economic, technological, ecological and social environment and interior world of supply chains and set new standards in terms of effectiveness. Graphically, the setting of change goals can be visualized as the replenishment of the cost-service-function function of a supply chain, possibly also as its curvature, equalization, etc. (Göpfert / Wehberg 1995). The objectives of competitiveness and sustainability, which are at the heart of digital supply chains, are also goals of change in this sense. Change goals also consider the different supply chain models where necessary to respond to more customized product portfolios and the change of customer behavior, properly.

Figure 3.1 Change profile of supply chain targets



One problem that arises in the structuring of the supply chain target system is the complexity of possible goals and **target relationships**, which results above all from the great opportunities for behaviour and design of supply chain processes. In other words, working out supply chain goals is a complex problem in itself (generally Adam 1983). For example, different supply chain models can overlap as far as they route back to the same semi-finished products and raw materials along the bill of materials. And efficiency levels depend on investments in supply chain infrastructure or eco partners, for instance. At least the following target relationships have to be distinguished, which may be complementary, indifferent and conflictual (Göpfert 1992):

- Intra-functional relationships within the objectives of the supply chain function (for example in the so-called "magic triangle" between supply chain costs, service and stocks).
- Inter-functional target relationships between logistics and other operational functional areas (eg logistics-oriented production versus production-oriented logistics).

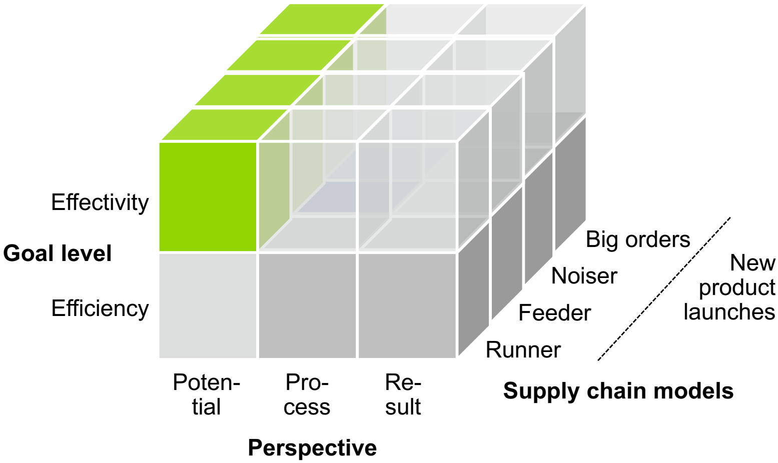
- Temporal relations (short-term and long-term goals).
- Relationships between company goals and individual goals of the employees (personal claim of the manager and goals of the logistics).

Key indicators offer the opportunity here to condense the facts of the complex reality that can be measured directly or via indicators: Search grids can provide structuring assistance in the context of an inductive key figure formation. It should be noted that the corresponding key performance indicators must be aligned with the process-oriented philosophy of supply chain management (Helfrich 1989 and Pfohl 1994).

A suitable structuring instrument is the **target cube** of supply chains shown in Figure 3.2. It suggests distinguishing between a **potential, process and result perspective** and connects them with the profiling variables of change and supply chain models in particular. Basically, all fields of the displayed cube can contain attractive target content. By way of example, from a process-oriented point of view, the effectiveness variable "process quality" (actual to target number of process interruptions, etc.) and the efficiency variable "process productivity" (km per trip, handling operations per hour, etc.) can be cited. It becomes clear that the effectiveness and potential perspective is subject to transformation and projects associated, while realizing efficiency results has to be addressed in a continuous improvement mode to a certain extend. If necessary, key figures from other areas of the company, such as production, procurement and disposal, must also be included in the supply chain target system. For example, supply chain management cannot improve performance if strategic sourcing suffers from a lack of market power and insufficient delivery of suppliers. And the Operating Equipment Effectiveness on the shop floor can heavily influence supply chains in case unplanned shut downs reduce the capacity available.

Last not least, supply chain model-specific targets have to reflect the nature of different demand patterns and thus steering mechanisms. In most cases it is pointless, for example, to set inventory targets for Noisers beyond process stocks. A lot of target-KPIs and reporting systems miss this kind of differentiation, which is one of the key route cases for the aforementioned **seeing-knowing gap**. Supply chain management typically has the data to differentiate between supply chain models but they don’t put the figures together in a way that generates insight to know what is going on.

Figure 3.2 Target cube of supply chain management



Another common problem for the development of relevant goals is that the scope of supply chain management and thus cost associated is being defined in a too narrow sense. The recording of supply chain costs in practice is by no means trivial. Often, only those costs that result from the tasks of the logistics and export department are added. However, holistic recording of supply chain costs, in the sense of a process-oriented approach, is the prerequisite for optimizing supply chains holistically on the cost side. When logging supply chain costs holistically, the supply chain practitioner is surprised in one case or another by the amount of these costs. Depending on the industry, **supply chain costs** can in many cases account for 15 to 20 percent of total value-added costs. In the nomenclature question of the definition of supply chain costs, it should be noted that only the costs of those activities are included in the supply chain costs, which can also be influenced by supply chain management (as a function). At the same time, it is vital that the management does control the entire supply chain in an end-to-end fashion. Capacity planning for example, is part of the cycle of production planning & detailed scheduling. But it is also essential to the sales & operations planning and the balancing of capacities in particular. For example, Bauernhansl (2014) estimates the **efficiency potential** of digital supply chains at 30 to 40 percent of the inventory costs or 10 to 20 percent of the supply chain costs and even 60 to 70 percent of the complexity costs, the definition of which may vary considerably.

In the context of a cost efficiency discussion for digital chains, it is vital to understand what transaction cost are. Actually, we can differentiate between process and **transaction costs** on the cost side. The concept of transaction costs builds on the approach of Williamson (1985 and 1991), which conceptually processes the presumption of Coase (1937), "... there is a cost of using the price mechanism". Consequently, transaction costs can be understood as the "costs of market coordination". While the number of new transactions in the course of digital supply chains is increasing, the level of specific transaction costs, which means the cost per transaction decreases due to the use of new technologies. This makes it possible to assemble new, individual processes for supply chains, in the extreme cases with a lot size N = 1, which means the service for each delivery is individualized and customized.

In practice, **benchmarking** is a popular way to derive goals. Although many business responsibles do have bad experience with benchmarking exercises just when it has not been performed properly, it can be helpful to compare different performance indicators between companies and businesses. Importantly, it has to be considered that supply chain networks typically have different structures, e.g. geographical footprints, technology and product portfolios. An apple-to-apple comparison has to take this into account. Actually, the comparison of structural characteristics can be even more insightful than comparing performance indicators. Sometimes, it is even better to avoid the expression "benchmarking" for exactly that reason. From the point of view of the resilient understanding of supply chains, however, it can offer starting points for developing new ideas from outside for the further development of digital supply chains:

Project example: Benchmarking of supply chain

Initial situation: Over the years, a company in the service sector has always concentrated on its service know-how and corresponding offer. Secondary services, such as supply chain management, were rather neglected because corporate management did not consider them to be particularly important to the company's success for a long time. After all, the services would not be "delivered" but would be provided by personnel and equipment, according to the company's mindset. Supply chain processes only played a role in the maintenance and servicing of plants, so to speak "in second place".

Objective: Due to the high pressure on margins, there was a growing need to examine all possible approaches to increase cost-efficiency and margin, so that supply chain processes should also be benchmarked. The results of the benchmarking process should be included in the target agreement process and implemented by the line managers.

Approach: Benchmarking was carried out using a four-step process: In the first stage, the scope of benchmarking was defined in terms of the criteria to be included, peer companies and the target level. Great emphasis was placed on a clear nomenclature. Depending on the availability of the reference data, a complementary primary survey of peer companies could be considered, which could be obtained for participation in the benchmarking process. In addition to a comparison with external companies, an internal comparison between locations was also carried out. In order to avoid delimitation problems, a process framework was used for the relevant supply chain processes.

The second stage of the benchmarking process involved collecting the data from pre-structured entry sheets. The survey at the various locations was accompanied on site to ensure a uniform understanding. In addition, the additional information relevant for comparability was collected. For example, stocks of spare parts could only be compared to the extent that their age and location were comparable. At the same time, it was important in this context to know which maintenance strategy underpinned the performance data in order to be able to discuss suitable measures later.

In the third stage, the comparability of the ensured data by means of a suitable normalization and carried out the company and location comparisons. As a result, efficiency and effectiveness gaps could be identified, which provided information on the potential for improvement in the supply chain.

The fourth stage then included discussions with those responsible to discuss the benchmarking outcomes and to adopt targets and next steps.

Result and digital supply chain relevance: As a result of the benchmarking, more than 10 percent efficiency improvements were defined, which corresponded to a higher double-digit million euro amount. In addition, there were a number of issues where the company should take better account of the service expectations of the market. Next to the earnings effects, benchmarking provided the opportunity to compare supply chain management with other companies in terms of content. The identified differences in efficiency and effectiveness indicators signaled different supply chain practices, including possible starting points in the sense of digitalization.

Factors of success: Three factors were of decisive importance for the success of benchmarking: Firstly, it was crucial that the supply chain processes and associated resource consumption were holistically covered by the process perspective. Secondly, the detailed coordination and transparency of the approach and methodology with those responsible was important. The so-called "buy-in" of the management is not self-evident, especially in times of many "praised" benchmarks. Most companies have gained extensive experience in benchmarking across a range of recent years and know that the validity and acceptability of the results are crucially dependent on the approach and methodology. A "jump in" in a benchmarking exercise according to the motto "we'll see what comes out", is therefore generally not advisable. Third, the methodology was in itself, for example, the clearly defined nomenclature and consistent normalization, critical to success in supply chain benchmarking.

3.2 Basic supply chain strategies

The implementation of the supply chain goals, which are initially defined in the target system, is achieved through strategic planning. However, the target planning also depends on the possible strategies or their feasibility. **Strategy** (strategos, Greek = army leader) is still often understood as a kind of martial arts or army leadership. It then easily leads to the view that competitors as well as consumers should be outsmarted, indeed defeated. Only if one loses, the other can win. However, such an understanding of the term has increasingly been replaced by the insight that competition between companies is not war. Rather, the task of the company has to be seen as improving solutions to customer problems and providing benefits to society in general. Strategies in this sense serve to build up and maintain such potential benefits. Such an understanding corresponds to the self-referential character of complex supply chain systems, takes into account the demands of stakeholders and enables the coevolution of the enterprise and the surrounding system (Mann 1995).

With regard to supply chain management, basic and functional strategies can be differentiated. **Functional strategies** address the specific contents of the individual supply chain sub-functions, e.g. transport, packaging, etc. They are decided in a rather decentral mode. Prospectively, this can take place autonomously, even in an automated way and in exchange with other cyber-physical systems. Bauernhansl (2014) also speaks of "shop-floor-near control loops". "If additional services are required, (...) the CPS (…) addresses business objects and services in its cloud. The result of business objects and services and thus the desired process is created on demand "(ten Hompel 2015, translated). As much as the development of supply chain systems is modeled in a self-organized manner or via (so-called meta) algorithms, the planning process has to be cascaded or even completely decentralized.

Basic strategies, on the other hand, relate to those structures of a supply chain that are defined across all sub-functions and connect with the business strategy. With regard to the possibilities derived from these structures, one can also speak of cross-sectional potentials. Important cross-sectional potentials arise above all from the targeted competitive advantage as well as the applied supply chain models and learning strategy. Basic supply chain strategies have to be planned according to the situation and thus have to be individual and specific. On the other hand, they can be summarized through relevant patterns.

One of the most common misunderstanding is to believe that basic strategies in the course of digital supply chains will initially not change so much. It is assumed that digitalization just impacts the customer journey and offers some use cases regarding supply chain functions. This is, however, typically not correct just because the potential of digital supply chains is not limited to the application of new technology within the supply chain. It also has to deal with higher complexity caused by digitalization, e.g. in terms of an individualized product portfolio and thus new supply chain models and capabilities required. Moreover, the customer experience does not stop at receiving a customer order. Delivering products provides a range of contact points with customers and thus outbound logistics is part of such journey. Last not least, customer needs ask for quite some supply chain relevant features in a digital environment, for instance transparency through tracking & tracing.

3.2.1 Competitive advantage

It has already been established that supply chain management should make a contribution to the competitiveness of the company. It can be the central core capability, which determines the competitive edge. The role that supply chains can play in the overall competition depends on its attractiveness with regard to cost reduction and differentiation potentials. The competition strategy of supply chain management is thus defined by the question of whether the minimization of supply chain-relevant costs or the maximization of the relevant customer value is aimed at (Porter 1986 and in addition Darr 1992, Delfmann 1990, Jünemann 1989, Poth 1991, Schiffers 1994, Weber / Kummer 1994 etc.).

In a graphical representation - with the delivery service on the abscissa and the supply chain costs on the ordinate - the former **cost leadership** strategy means an attempt to shift the supply chain cost-service curve downwards (Göpfert / Wehberg 1995). By influencing relevant cost drivers, the lowest possible cost level with sufficient service level is sought. The latter **differentiation** strategy, on the other hand, represents the endeavour to shift the cost-service function of logistics to the right. The consideration of the competitive advantage to be achieved is completed by the option of processing the entire market with a uniform logistics standard or segmenting it into several niches to be served individually, whereby the **niche strategy** tends to correspond to the striving for differentiation. Because the more manageable the served market, the sooner it is possible to respond to the individual service needs of customers. Digital business and business models often correspond to segmentation and niche because the use of new technologies makes the cost of such a differentiated market processing manageable. In this context, Anderson (2007) speaks of "long tail" and a 98-percent rule that replaces the previous 80:20 rule. The extent of the complexity of the supply chain planning system brought about by the competitive strategy then increases. Figure 3.4 shows a corresponding change profile of possible competition strategies in supply chain management. It shows the polarization of supply chain patterns of behaviour in the form of more stability-oriented cost dominance on the one hand and change-oriented benefit dominance on the other.

A differentiation or niche strategy has to build on customer needs and address them explicitly. Clay, Mashall and Glynn (2017) have elaborated such needs in a changing world considering new, digital technologies. Their research has been summarized by a description of Dawn, a 25 years old girl representing the typical customer behaviour of the future, let`s call her **Dawn Digital**. Dawn Digital is characterized by the following behaviour amongst others:

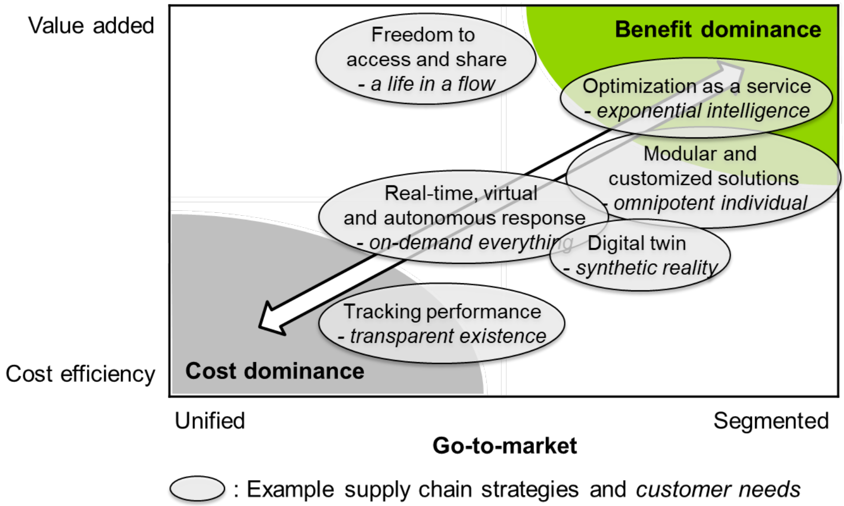
- She doesn’t know how to drive, however, she`s driving all the time,
- She’s never been to a doctor, but she visits her doctor every week,
- She never logs on, but she is indeed always online,
- She’s always shopping, however, she’s never in line,
- She’s never ever been “lost”,
- Her T-shirt is connected to the web,
- Her tattoo does unlock her car,
- And her superior is a robot.

This behavior is no science fiction, nor is it even a particularly extreme perspective on technological influence. It’s more a sketch of a not too far away future full of disruption. Digital technology won't just change the customer experience, however, change how the world works and thus supply chains operate. It changes "how people connect, create, escape, accomplish, work, unwind, understand, stand out, fit in, get smart, get well, get money and simply live" (Clay / Mashall / Glynn 2017). Key questions from a differentiation perspective are, conclusively:

- What does supply chain management need to do differently to meet the needs of the customer of the future?
- How will the value proposition and supply chain model need to change?
- How do we stay relevant to Dawn and what can supply chain management do to support this?

Selected customer needs and supply chain propositions to respond to it are shown in Figure 3.3. The question of whether the competitive behaviour of supply chain management is more stable or change-oriented certainly does not depend solely on the desired competitive advantage and the form of market development itself, as also shown in Figure 3.3. Rather, the concrete change in supply chains must always be viewed against the background of its further basic strategic considerations. In particular, the consequences for supply chains deriving from a market-growth/market-share portfolio determine their exact degree of complexity (Klimke 1983). Thus, so-called **dogs**, in which supply chains try to minimize inventories and distribution costs in particular, are more likely to be associated with cost-dominated patterns of behaviour. The endeavour to design the service processes as economically efficient as possible implies stability-oriented management structures. In contrast, the role of supply chains in so-called **stars** are, according to its principle, probably more benefit-dominated. The favourable competitive position makes it easier to keep pace with the dynamics of the competitive environment in the form of change-oriented behavioural patterns.

Figure 3.3 Change profile of the competitive strategy of supply chain management (needs by Clay / Mashall / Glynn, 2017)



Competitive positions are often defined in the company at the product or service level because in the first place the positioning question is not about the competitiveness of the company as a whole, but always about its offering in particular. In individual cases, this may mean that the supply chain of a company is highly differentiated according to customer segments, product areas and regions, but this does not change the basic considerations regarding the competitive strategy of supply chain management. In other cases, supply chain management is not considered at all, just because a very **product-focused mindset** and happy-engineering culture does not recognize the potential of supply chain management, traditionally. This, however, is changing the faster products are being commoditized and digital strategies are seeking for support in operations. Then, secondary service like supply chain management become a competitive factor and appreciated by the businesses of a company, which is being recognized even outside the supply chain management department.

Supply chain management as a secondary service of companies thus is the differentiating factor in many markets with almost interchangeable or commoditized products. The following project example shows the contribution that digital supply chains can make to customer loyalty:

Project example: Smart customer retention

Initial situation: In the course of a customer survey, a manufacturing company determined that its customers considered the product range to be almost completely interchangeable with its competitors. One of the main reasons why customers were loyal to the company was good service, according to the results of the survey. In the face of increasing customer turnover, the company faced the challenge of recognizing impending customer shifts as early as possible in order to be able to take countermeasures in this case. The importance of customer loyalty was due in particular to the high acquisition costs for winning new customers. It was significantly more valuable for the company to retain existing customers than to attract new customers.

Objective: The company specifically aimed to halt the increase in the turnover of relevant customers within the next 12 months and halve fluctuation within two years. Impending losses of valued customers should be identified in good time by the use of big data and predictive analytics in order to be able to implement countermeasures in individual cases. If acquisition efforts remain unchanged, this should significantly increase growth over the next two years.

Approach: The company started a four-step process. In the first stage, comprehensive data from 14 categories was collated in one database. This included the operational data of service provision (service quality, value-added services, sales and marketing activities, etc.), the master data of the customer company (seat, size, sector, etc.), personal data of the purchasing-relevant customer employees (hobbies, marital status, career level, etc.), customer satisfaction with the product range and service of the company (attitude, recommendation behaviour, willingness to change, etc.), their ordering, acceptance and complaint behaviour (sales, lot size, order times, etc.), the market conditions in the respective customer segment. (price pressure, service relevance, etc.), competitive behaviour (campaigns, innovation, etc.) and corresponding changes in these factors over time. In the second stage, a change index based on static pattern prediction methods was introduced, classifying customers by customer value and a net loyalty index (NLI), which essentially expresses the probability of exchange. High value customers and NLI were statistically demarcated. These were in the third stage in the focus to derive appropriate countermeasures. For example, the service level was increased, additional value-added services were offered, a feedback call was held on-site, etc. in order to counteract a change in the respective customer and to better understand potential route causes of losing them. The effectiveness of these customer loyalty measures depending on the respective customer profile was also included in the analysis. In the fourth stage, the newly established customer loyalty process was anchored in the line organization. If possible, the interfaces to the data sources (CRM, social media, etc.) were IT-technically mapped, in order to avoid media breaks or system interfaces. An incentive system for sales and service employees has been set up to participate in improving the data and early warning indicators taken into account.

Results and digital relevance: As a result, 74 percent of the customers who were considering a change of supplier were identified. This means that the second type of mistake, i.e. willing customers who were not identified early, was therefore 26 percent. The error of the first kind, by contrast, the false identification of loyal customers without the intention of switching was 14 percent. Both errors could be further reduced over time. In order to derive suitable countermeasures, the main factors of a higher willingness to change were identified. In particular, 24 percent of the supply chain service determined the loyalty of customers. The company's goals of increasing customer loyalty and growth have been achieved.

Success factors: Decisive factors for the successful implementation of the project were above all the comprehensive consideration of customer-relevant data and the possibilities of statistical procedures. on the pattern prediction and the consideration of supply chain service as a differentiation factor in the company's competition.

Internet of supply chain services

Digital technology allows for individualization within the supply chain, for example through service differentiation according to different customer segments. This supports the dominance of benefits. Digital supply chains additionally offer the opportunity to offer completely new value-added services and to further develop the business model of the company in a hybrid (virtual / real) way. Insofar as such services are represented via cyber-physical systems on the Internet, it is also possible to speak of an Internet of services, here the **internet of supply chain services**.

A synonym for new services is the mobile software application ("app"), which is a software application with access to mobile devices such as tablet PC or smart phone. It is less about the "app" itself, but about having certain information available at all times, making specific decisions at any time or being able to link selected processes anywhere. This can be z. These include, for example, the ordering of so-called intelligent products per se, the actual-time transparency regarding the delivery and status of customs clearance, the subsequent change of a service level and the control of outsourced activities. The possibilities offered by Logistics 4.0, especially in customer service, will play a major role. Here, the now cost-effective use of sensors allows so-called predictive maintenance concepts to economically implement, which can be connected to the spare parts logistics. The use of cyber-physical systems then allows machines to virtually order their own spare parts as needed and prevent previous media breaks. Such new logistics services can deliver significant added value from the customer's perspective.

The role of an in-house service provider may also be internal services, such as the provision of a control cockpit to track workload utilization and other logistics metrics. This can also help to increase the benefit for the internal customer, which means to assist him in achieving his goals. And also, the provision of IT services for supply chains marks a possibility of the internet of services.

As an example of the possibilities of digital supply chains to develop new services and to exploit the networking potential, the following case of application is outlined:

Project example: Crowd logistics

Initial situation: A logistics service provider in the field of courier, express and parcel services (CEP) saw digitization as a strategic opportunity. He set up a scouting team to identify new services with business potential. A starting point for this was the available transaction data of mobile phone users, which are marketed by mobile operators.

Objective: The aim of the initiative was to define and implement services based on available transaction data, which were able to develop the core business profitably. Also, the company wanted to profile itself with such innovative services in the market as a digital supplier in order to use image effects.

Approach: The initiative was structured in four steps. In the first step, a study was used to narrow down the services in question, detailing them in terms of process, developing an appropriate IT application ("app") and designing a business case. The CEP service provider had the intention to integrate mobile users for delivery in the last mile in the area. With broad involvement of the population in certain areas, the last mile could be largely covered in this way by third parties, which are already on the ground and have certain patterns of movement. This approach was referred to as Crowd Logistics. In special cases, one could also imagine pickup by the addressee if this can be organized efficiently due to the movement data. In this case the addressed became a service provider for himself, in a way he became a "prosumer" (= producer and consumer). In the second step, the feasibility was checked. In order to respect data protection, the mobile operators provided the movement data only in anonymous form. This asked for special requirements on the selection of the participants for the crowd logistics, because only certain types of movement patterns were interesting for the mapping of the last mile. The subscription process was designed to ensure that it was appropriately selected. The pilot in the third step gave a more realistic picture and showed fine adjustment requirements. In the fourth step, the new services were rolled out across the different regions.

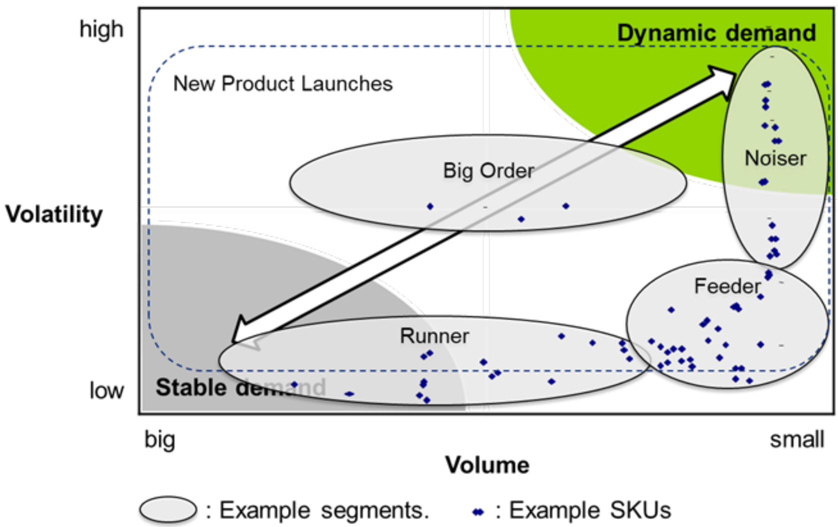
Result and 4.0 relevance: In addition to the positive positioning through the creative service idea, the new service offered savings potential in the process costs of the last mile in the double-digit percentage range. This already took into account that the subscribers received a premium for each delivery accepted. Crowd logistics proved valuable in urban areas because there were enough digital traces to reconcile the collective behaviour of subscribers with the needs of supply chain management. It proved to be efficient in structurally weak areas because the out-of-service costs of the CEP service provider could only be reduced to a few shipments.

Success Factors: Decisive factors in the implementation of the new service idea included compliance with data protection requirements and the user-friendliness of the IT application. In order to develop the idea itself, it was crucial to have an ongoing overview of correspondingly available data and new business models of relevant market participants, in this case the mobile service providers. Without a corresponding scouting on the market, the CEP service provider would have missed this opportunity.

3.2.2 Sales & operations planning

Many companies do have one approach to manage their supply chain. In many instances, service levels are managed via stocks, accordingly. To meet market requirements and leverage the full potential of digitalization, however, it is typically not good enough to design one supply chain overall. There is no one-fits-all approach when it comes to steering mechanisms, target inventories, lead times, service levels, reporting, pricing and so forth. Different demand patterns ask for different supply chains with distinguished characteristics and design principles associated. This is what we call **supply chain models**. A supply chain model is an operating system to develop, design and manage a supply chain in line with its specific demand as well as other requirements.

Figure 3.4 Change profile of supply chain models



Dependent on how stable or dynamic the demand for a specific product is, we can distinguish five different types of supply chain models (Figure 3.4):

- **Runners** show high annual volumes with stable demand characteristics. Runners are often representing a baseload as they are determining a major share of the utilization of supply chain infrastructure. Runners are relatively easy to handle from a supply chain management point of view because the can be easily forecasted and don't cause surprises.
- Opposed to Runners, **Noisers** are ordered in smaller lot sizes with a high volatility. The demand of single Noiser products is thus difficult or even impossible to forecast. Noisers typically represent rather customized and niche products. They require a thorough management for their relatively high process cost, compared to Runners.
- **Feeders** are ordered in smaller lots than Runners but still reasonably sized and less volatile in demand than Noisers. Therefore, Feeders can better be forecasted. They are called Feeders because they typically provide the opportunity for increasing the utilization of production assets by "feeding" inbetween other lots within the production planning and scheduiling.

- **Big Orders** combine the characteristics of Runners and Noisers in a way that they represent large single lot sizes, which are being ordered once for a while. Rather Just because Big Orders do not show a steady inflow they are not easy to predict, however, challenge the delivery as well as production infrastructure for their high volumes.
- **New Product Launches** represent any new offerings that are being introduced to new or existing customers. In order to realize a proper time-to-market and scale-up of new offerings, supply chain management must determine the steering mechanisms of such as early as possible. New Product Launches can be Runners, Feeders, Noisers or Big Orders. The flip side of New Product Launches is the portfolio de-proliferation, which can challenge supply chain management in a similar way than managing the time-to-market.

The impact of supply chain models is significant. However, segmenting products for supply chain models is simple. You can do this segmentation for supply chain models even in Excel, based on an excerpt of the relevant ERP data like the following example:

- **Average:** grand total / # of data point (# of weeks)
- **Standard deviation:** STDEV.P(aa:zz)
- **Coefficient of variation (CV):** StdDev / Average
- **Runner-Feeder-Noiser:** =IF(CV<=0,75;"R";IF(CV<=1,33;"F";"N")).

Importantly, the definition of supply chain models refers to **demand characteristics of external markets**. There is no use in analyzing the structure of internal production orders as a basis for building supply chain models. Sometimes, supply chain managers refer to the demand structure of their internal customers if there is a lot of inter-company delivery and the responsibility is limited to single sites or production steps only. Even worse if internal silos are representing a multi-step production process at different sites with distributed responsibilities and missing overall alignment. In this case, the internal decision making easily creates its own internal complexity far away from market behavior. This, however, turns it around and is not the way supply chain models as well as design principles associated should be determined. Internal orders and respective lot sizes are subject to the design of supply chains consistent with pre-defined models, and not vice versa.

Once, the right supply chain model for a product is defined, supply chain management can attach key design principles to determine the way how to handle it. Of course, **key design principles** and parameters in particular have to be set individually for each business and company. There are repeating patterns though, shown in

Figure 3.5, which supply chain management can refer to without reinventing the wheel again and again. In line with the end-to-end perspective of digital supply chains, all relevant functions need to be involved when determining those design principles in order to define a common ground how to operate. For example, it is vital that the high process cost of Noisers and their Make-to-Order procedures are being considered within the pricing approach of the Sales organization. Lot sizes of Noisers are small and thus change-over cost typically high. And Procurement must secure the necessary flexibility at suppliers in terms of their Available-to-Promise (ATP) involvement for such. For each supply chain model, coherent principles then facilitate a cross -functional alignment rather than seeking for manual coordination on a case-by-case basis.

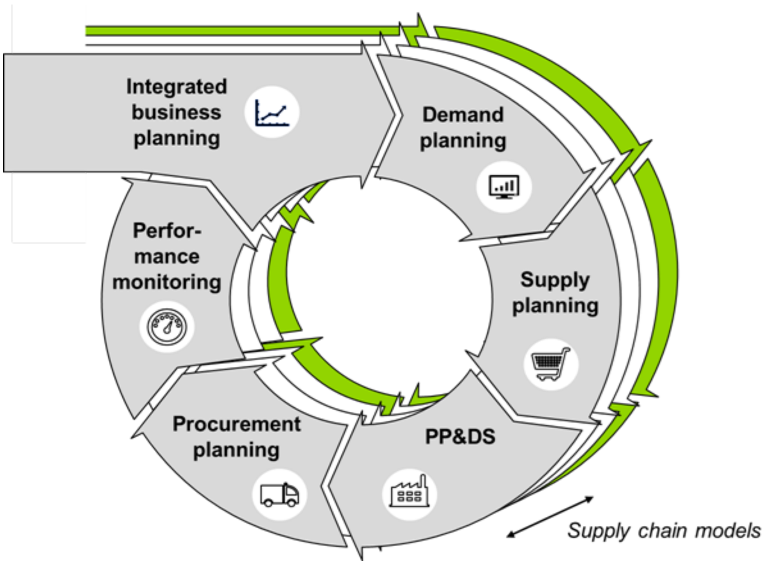
Figure 3.5 Key design principles of supply chain models

- EXAMPLE -	Item	Runner	Feeder	Noiser	New Products
Production	**Monthly volume**	XXX units	YYY units	ZZZZ units	Target KPIs dependent on expected demand and thus SC model, incl. ramp-up
	Average lot size	optimum	variable	variable	
	Scheduling	Make-to-delivery	Make-to-stock	Make-to-order	
Supply chain	**Flexibility**	Demand stable, flexibility thus not important	Monthly demand predictable, Limited flexibility required	No detailed planning, Placeholder capacity	
	Punctuality	Daily basis	Daily to weekly	Weekly or more	
	FC accuracy	xx%	>yy%	-	
	Reliability	xx%	≥yy%	<zz%	
	Delivery time	Continuous	y days	ATP based	
	Target DOH	xx	yy	zz	
	Target cost	- M EUR and -XXX FTE (vs. baseline 2016)			
Procurement	**Supplier reliability**	x% service	y% service	ATP based	
Sales	**Margin**	Secure base profitability	Increase/ smoothen profitability	Opportunistic Noiser margins	

Following the typical design principals for the relevant supply chain models, traditional forecasting of the demand of single products really works with selected models only, like Feeders. Other supply chain models like Noisers are facilitated by other approaches, e.g. forecasting of the demand of placeholder capacity, which means forecasting on a product group level, that determines buckets for capacity utilization of a single production asset.

For seeking alignment and consensus as to demand and supply, organizations run a **sales & operations planning** (S&OP) exercise. Many S&OP processes suffer from the attempt to handle all products the same way without considering the different nature of each of such models. While the approach of planning and forecasting is specific for each supply chain model, i.e. its method, tools and content, formal responsibilities of S&OP can be similar or even the same. Many companies, though, do have specialized S&OP managers for each supply chain model. Figure 3.6 shows a typical S&OP process including its differentiation for respective models.

Figure 3.6 Sales & operations planning (S&OP) for digital supply chains

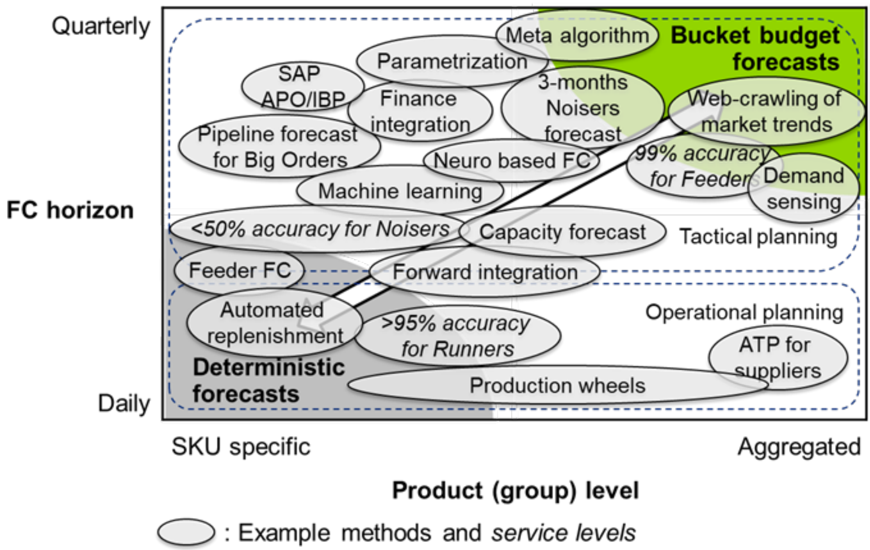


The quality of the S&OP is determined by the following key success factors, which ask the planning and forecasting to be:

- Cross-functionally integrated (Strategy, Sales, Procurement, Finance, …),
- Bi-directional (multi-loop alignment between demand and supply),
- Cross-site (balancing capacities and material),
- Multi-dimensional (volumes, revenues, margins),
- System and alert-based and thus managing by exception (not manual),

- Continuously improved (regular review and refinement),
- Independently governed (e.g. neither by Sales nor by Production),
- Supply chain model-specific (e.g. ATP for Noisers).

Figure 3.7 Change profile of tactical and operational planning



Predictive analytics can help to enhance forecasts and get more value out data. The results can be fed into respective S&OP systems, e.g. SAP IBP or Demand Solution. Over and beyond shaping relevant parameters of the system itself, artificial intelligence then helps to identify adjustment needs, e.g. by regular reviews of market factors based on web-crawling appliances. On this basis, it can support developing planning algorithms in line with environmental changes, automatically. In this situation, so called meta-algorithms help to increase the degree of automatization and to further reduce management-by-exception efforts initiated by alerts. Figure 3.7 visualizes the change profile of relevant planning methods, selected use cases and service levels associated with key supply chain models.

Now, in addition to the aforementioned basic patterns of competitive behaviour and corresponding supply chain models, another concept assumes that competitive advantages are based on the unique assets of companies, especially their knowledge and know-how. With a few unique capabilities of the company, the so-called core competencies, competitive advantages are established thereafter (D'Aveni 1995). Supply chain management can certainly become a core competence (e.g. Sauer-Brey 1991). In this context, it represents the result of learning processes. We will therefore discuss the learning construct in more detail below.

3.2.3 Learning

Organizational learning

The supply chain competence of a company can determine its competitive position quite substantially. But many companies have to realize that they rather have too little of respective competencies. In other words, there is a **shortage of supply chain expertise**. This applies in quantitative terms, i.e. number of relevant employees, but also in terms of quality, i.e. depth and scope of specific supply chain expertise. Many companies limit themselves to the development and maintenance of their competences. They channel the skills of their employees and organization as a whole mainly on product-relevant knowledge. For example, many manufacturing companies love to do happy engineering and high-sophisticated product development. In the past, supply chain management was rather understood as simple delivery, "truck driving" or even "pallet pushing". At the same time, there is a growing awareness that, in times of ever more homogenous products, any secondary services such as supply chain management can be decisive. And so are corresponding skills and appropriate learning. This applies all the more to the character of digital supply chains. A digitalization strategy of a company that is limited to the customer journey will fail. It also needs the "motor room" in place, which means digital supply chains are key facilitator for respective strategies. Here, supply chain management becomes business-relevant, creates impact and makes a difference towards customers.

Let`s talk a bit about learning. Learning means multiplying knowledge in the broadest sense. (Probst / Büchel 1994) It is the central prerequisite for the autonomy of a system as well as for its survivability in general. A self-contained learning theory does not exist so far. Rather, learning-theoretical explanatory approaches are to be differentiated. Some focus on emotional-activating determinants and work with stimulus-response patterns, such as classical emotional conditioning. Others are based on cognitive-rational considerations dealing with complex issues in the sense of an insightful illuminate learning (Meffert 1992). Models of **hierarchical learning** structures build on the idea that learning complex issues first requires the handling of simpler contents. Due to the complexity of supply chains on the one hand and the primarily rational behaviour of such management on the other hand, the cognitively rational explanatory approaches are especially relevant in the following.

Furthermore, individual learning should be separated from **organizational learning** in supply chain management (Probst 1994, and Probst / Büchel 1994): Individual learning includes the intrapersonal processing of supply chain employees, which are related to knowledge building. By contrast, organizational learning encompasses the knowledge base of the supply chain system as a whole, not just as the sum of individual learning activities. It expresses the interactions between the members of supply chain. And, in particular, it represents its independent record and the (re-) accessibility of knowledge (supplementing Vester 1994). According to this, an independent quality is to be attributed to organizational learning. On the other hand, individual learning in supply chains and the organizational learning of supply chains do have a "**shared reality**" common. This shared reality consists of the needs, attitudes and values of several system members. Organizational learning is also referred to as the process of changing "cognitive maps" or "social reality constructs". It is defined, as it were, by the intersection of the many-layered contexts of supply chain employees. To a certain extent, the motor of learning are the convergences and divergences in the contexts or realities. The "**art of learning**" is to maintain a balance between convergences and divergences (Cohen / Levinthal 1990 and Fiol 1993).

Problem solving skills

Learning can be understood in a quantitative and qualitative dimension. Before presenting some of the key factors that determine the extent of learning (quantitative dimension) in the following point, the first step is to look at the different ways of learning (qualitative dimension). Learning is not the same as learning. Supply chain management, like corporate management in general, knows three ways, learning solutions, learning problem-solving skills, and meta-learning (similar, but generally Argyris / Schön 1978):

Learning solutions is the efficient adaptation to given goals in relatively stable environments. It includes the correction of existing implicit patterns of behavior or the unconscious knowledge base of supply chain management. Such learning is expressed, for example, by experience in packaging and handling processes as well as by exercise gains in route planning. Failure to achieve the right goals gives the impetus for learning processes. The latter goes hand in hand with the confirmation, and in part also with the refinement of the knowledge base of a supply chain. For example, when drones learn from each other to optimize transport routes, this affects solution learning. The latter is an optimization lever that should not be underestimated in the interests of supply chain efficiency.

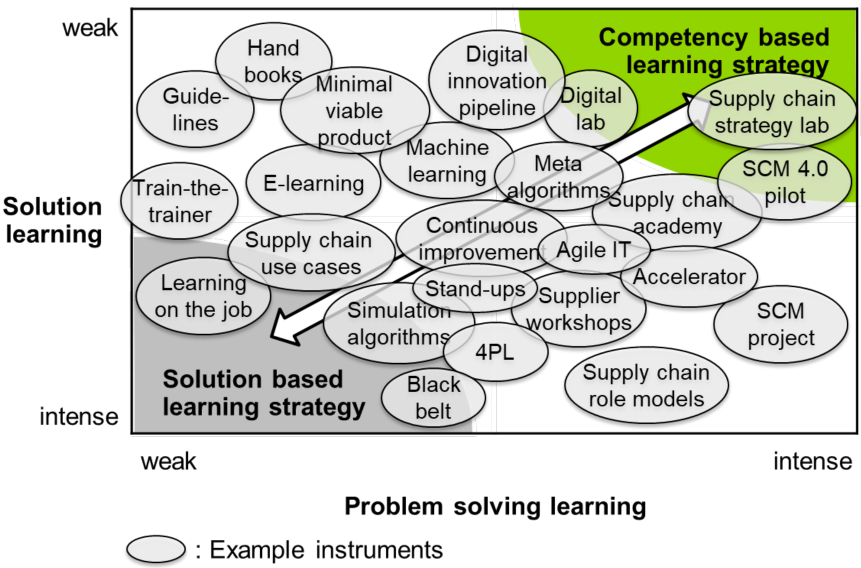
Compared to the learning of solutions, the **learning of problem solving skills** refers to the further development of the conscious knowledge base of supply chain management. The expediency of the otherwise fixed, seemingly inviolable formal goals of supply chain management is called into question. New priorities are set and competences expanded. The learning of problem-solving abilities includes the self-development of such new competences, for example in the form of the development of meta-algorithms, that is to say rules of behavior for adapting existing or developing new algorithms.

The learning of problem-solving skills is also accompanied by a reorientation in normative terms. Problem-solving skills cannot simply be "slipped over" to management. They require a corresponding conviction, the insight into their usefulness, even meaningfulness. This very fact, the lack of benefit or meaning, is at the same time also the "driving force" of this kind of learning.

For example, a company may feel compelled to segment its customers and differentiate the delivery service by priority of those segments. Building such segmentation skills may be driven by the belief that equal treatment of all clients, irrespective of their strategic importance and profitability, does not make sense. In that case, the company and supply chain in particular are applying new problem-solving capabilities to effectively serve its customers. Likewise, the evolution of the supply chain in terms of digitalization requires new problem-solving abilities. Because many potential solutions are not yet known or widely used due to the pacemaker nature of technologies such as cyberphysics. And especially the stronger self-control of supply chain processes, for example in manufacturing, requires a higher (problem-solving) competence (Spath 2013).

Different **levels of competence** can be distinguished. Against the background of the logistical nature inherent in supply chain management, a largely uncoordinated form of task fulfillment characterizes the lowest level of competence. This level of problem-solving ability can be referred to as "pre-supply chain management." In a second stage, "supply-chain-interested parties" begin to deal for the first time with the coordination idea of supply chain management. For example, pilot studies and proof-of-concepts provide the formal framework here. At first conceptualization attempts so-called "supply chain beginners" dare. However, their efforts still remain at the conceptual level due to their overall low problem-solving abilities. Island solutions are still the rule. On the other hand, "advanced supply chains" succeed in enforcing a holistic concept, which at the level of "supply chain professionals" has developed into competitive advantages over the competition. Finally, at the highest level of competence, which is referred to as "post-supply chain management", the respective concept lives on all levels of the hierarchy. An explicit consideration of the resulting coordination tasks is then no longer required. Supply chain management becomes the self-understanding of corporate management (Weber / Kummer 1994).

Figure 3.8 Change profile of organizational learning within supply chains



Companies that are still dealing with the basics of supply chain management will probably be overwhelmed by the confrontation with even more complex forms of the digitalization and "hang out" their employees. Due to its high innovative character, the organization of digital supply chains requires a high level of competence. Hence, supply chain professionals or post-supply chain specialists are needed. The learning of problem-solving skills is not to be understood as a one-off and then completed way. Rather, it is a recurrent, revolving process that involves improved **learning of learning** or meta-learning. This becomes evident when one realizes that in the course of learning, one probably does not acquire the supply chain competence par excellence. Instead, one learns in relation to many different facts. The devil is in the details. In addition, it can be assumed that problem-solving abilities acquired in a dynamic environment will in a sense age. A permanent learning is the result.

To sum up, combining these two types can be contrasted with two polar types, the competence-oriented learning strategy and the solution-oriented learning strategy of supply chains or supply chain management, respectively (Figure 3.8). The former corresponded to change-oriented, the latter with stability-oriented supply chain structures. Because the number of possible manifestations of the knowledge base of supply chains increases with increasing intensity of competence-oriented learning, which increases the degree of complexity of the supply chain planning system caused by the learning strategy.

Diffusion

The theory that attempts to describe, explain and shape the acceptance and dissemination of knowledge in social groups is the theory of diffusion and adoption (hereinafter referred to as Backhaus 1990 and Meffert 1986). The question of the learning drivers and obstacles of (digital) supply chains is thus directed towards the adoption and diffusion of such know-how. In this context, adoption models try to answer the question of whether managers accept innovations in the field of supply chains and on which the acceptance of these innovations depends. Sociologically oriented diffusion research is then concerned with the dissemination of innovations over time, understood as the sum of all adoption processes. The status of research on the **diffusion drivers** of supply chains is currently considered to be low (but Göpfert / Wehberg 1996 b). At this point, therefore, an overview of hypothetical diffusion drivers and barriers must be limited. It is possible to distinguish know-how versus adopter-specific influencing variables. Among the know-how-specific factors are the drivers and obstacles to learning that arise from the peculiarities of the respective problem-solving abilities. According to experience, this includes factors such as the relative advantage, the compatibility, the complexity as well as the testability of the competency innovation:

- The **relative advantage** describes the benefits that an innovation offers compared to its alternatives. The competitive and social benefits of digital supply chains have already been discussed several times. According to this, the opportunities associated with such a build-up of competencies depend above all on the attractiveness of supply chain management and digital supply chains in particular. Many manufacturing companies, for example, that discuss digitalization do have pre-mature supply chains and thus face significant potential of doing both. They can benefit from developing their supply chain management as well as from executing their digitalization strategy, significantly.

- **Compatibility** is the ability to integrate into the existing. New problem-solving abilities can be introduced all the more promisingly if they modify what has been done so far, and thus rely on existing structures instead of completely knocking them over in order to then proclaim their rebuilding. The development competence is compatible insofar as it corrects the previous approaches of supply chain management in the direction of a resilient perception of already existing tasks and does not aim to create completely new supply chain specific functions.

  In the case of digital supply chains and related technology, the compatibility of the referenced systems often is still inadequate. This applies less to the ERP systems, in which a few large providers already ensure a high degree of compatibility. In the field of production planning and control, however, the provider landscape of corresponding CIM or **MES** systems is comparatively fragmented (similar to Soder 2014). In some cases, suitable standards that guarantee compatibility between systems are missing. For this reason, the latter are currently being discussed intensively under the heading "**de facto standards**" in the Industrie 4.0 community.

  In addition to the IT infrastructure, Nyhuis et al. (2008) show the criteria for the adaptability of **robotics** systems, which is also still at the beginning (but Steegmüller / Zürn 2014). In addition, there are issues of data security, reaction time and energy-saving. For **data security** considerations, a European open cloud (cloud) is ideally needed on the basis of unified requirements, the responses in actual time; which means in the millisecond range. And taking into account Moore's law (Moore 1965) for regularly doubling the performance of computer chips, digital supply chains also need **energy-saving** solutions in view of the high IT capacity requirements in terms of a green IT. All this influences the compatibility of digital supply chains.

- In addition to compatibility, the extent of the difficulties that supply chain management will face in addressing new problem-solving abilities will also be driven by the **complexity** of skill innovation. Since the development competence as to digital supply chains is to be attributed a high degree of innovation, and even has a paradigmatic character, the uncertainty of the management caused by the diffusion process can be correspondingly huge. New paradigms struggle for recognition for a long time at the beginning of their life cycle before their potential is widely recognized and their diffusion accelerated (Kuhn 1967). In the context of the learning processes, it must therefore be ensured that the innovations to be processed remain manageable for the management. Learning in "small steps" is more useful here than the "big litter". Considerable resistances are otherwise the result.

Corresponding transformations journeys have to be organized in a smart way, accordingly. It`s not good enough to get to know the elephant but you need to slice him properly in order to succeed. Therefore, the discussion how to introduce, pilot and **roll-out digital supply chains** is of highest importance. Considering that the S&OP process and supply chain models associated are at the heart of digital supply chains, it can be reasonable to structure the journey for sites, for example. The S&OP includes the PPDS process on site just because capacity planning is subject to both. And PPDS principles have to be reviewed in the light of mass customization and portfolio shifts, accordingly. This is why capacity planning can be a focus point and needs to be developed, site specifically, in order to make a roll-out of the digital supply chain a success.

- Finally, the **testability** of a new competence marks the option for management to minimize fear of contact by "trying it out". A digital twin in terms of simulation games and practical examples on cyber-physical systems supports the awareness of management. And learning-by-doing with means of proof-of-concepts as well as pilots promotes a higher understanding of what a digital supply chain is. The profound cultural changes that accompany them indicate, however, that the learning of such problem-solving skills is rather a lengthy process. This is why it is even more important to follow an agile approach of continuous improvement rather than one-off waterfall initiatives.

The **adopter-specific parameters** describe the characteristics of the supply chain (management) itself that determine the learning behaviour. They are of central importance insofar as learning is largely a self-organizing process and thus not alienated by the adopters. Basically, subjects to learning can include both supply chain managers as well as logistics machines that learn. Favourable framework conditions, for example in the form of a "learn-shop digital supply chain" (generally Reichart 1984), can be created and give impulses. Both the competence-oriented and the solution-oriented learning of supply chains, as already mentioned, are primarily determined by the respective contexts of their system members. The divergences or convergences between the contexts thus become a central **learning driver**. The causes of divergences can, for example, lie in the different training of supply chain employees, partly in engineering and partly in business management. It can be assumed that the relationship between context **divergences** and the extent of learning suggests a bell-shaped course. If the learning behaviour is increased towards divergent contexts, from a certain point on, the discrepancies become so great that they lead to counter-productive conflicts. They then hinder learning rather than promoting it (similar to Kirsch 1976). Other adopter-specific learning drivers include **risk appetite** (Probst 1987) and **innovation orientation** (this is accompanied by an appropriate future development) in supply chain management as well as **perceived environmental complexity** and the resulting misfit.

In addition to the latter intra-personal factors, other interpersonal behavioural determinants also influence the learning of logistics. So-called **opinion leaders** occupy a central position in the communication structure of supply chain management and thus have multiplicative effects on the diffusion process. They fulfil a risk reduction task for supply chains when setting benchmarks. Because of their high influence, they usually function as power and professional promoters (Witte 1977). On the other hand, **taboos** or so-called non-discussables, significantly impede the learning process (Probst 1987).

The supply chain academy is ideal for anchoring the learning process in the company and digital supply chain in particular. The following use case illustrates its use in practice:

Project example: Supply Chain Academy

Initial situation: A manufacturing company had to recognize that numerous opportunities for further development of the business had its origins in its supply chain. However, respective skills were limited in terms of quality and quantity because of the traditional focus on manufacturing and sales. The attempt to recruit individual supply chain executives on board via recruitment consultants was partially successful. However, such an approach could not cover the demand in this area of the organization with regards to quantity. In the case of external training on supply chain management, the company found that these were more generic because company-specific issues were not adequately addressed. It lacked the "barn odor".

Objective: The company management decided to set up a supply chain academy in order to build up the required competences in-house, to anchor the topic of supply chain management internally and to be able to specifically address the corresponding possibilities for improvement. The aim of the academy was to train some 150 supply chain experts over the next three years who were not available on the market or who did not want to build up the company in addition to the existing employees.

Approach: The Supply Chain Academy was set up in three steps: First, a company-specific training program was developed, which took account of the company's competence requirements. To support the e-learning training, web-based training modules have been developed or adapted. The target group of employees to be included has been identified for each business area and academy-specific degrees have been defined, for example the "advanced supply chain" and "supply chain professional". In the second step, the training program of the Supply Chain Academy was piloted. Based on the pilot, possible improvements to the training content and procedures were identified and incorporated. In the third step, the supply chain academy was rolled out company-wide.

Result and digital relevance: Due to the high level of acceptance among the employees, the company's internal demand for training measures was higher than the demand, so that the Supply Chain Academy was able to exceed the training goals set. For the future, the company also saw itself well prepared for the learning content of digital supply chains due to the now established systematic development platform for its employees.

Success Factors: Two factors were particularly critical for success. On the one hand, the training requirements were closely geared to the company-specific requirements, which made it possible to directly apply the competencies conveyed. In doing so, the company found the right balance of training content between the imparted technical solutions and strategic competencies for problem solving. On the other hand, the attendance at the Supply Chain Academy was perceived by the employees as an individual step of development due to the awarded degrees, so that the personal motivation was very high.

Learning, planning and competition strategy revealed the most important basic strategies of supply chain management. The functional strategies of logistics now have to be explained.

3.3 Functional strategies

The task of supply chains is basically the management of spatio-temporal as well as the related transformations. Defined processes cause such transformations. (Pfohl / Stölzle 1992, Zöllner 1990, Göpfert / Wehberg 1995). For example, separation processes affect a transformation with regard to the quality of the goods. Warehousing is facilitating the transformation of time, and so forth. These supply chain processes mainly relate to the flow of materials, goods, residues and spare parts, to the flow of information and to the design of supply chain potential.

While the steering and development tasks of supply chains have a greater relation to their management system, the remaining processes are primarily directed to the execution level (similar to Pfohl 1990). The various processes build on each other. Certain processes include others or presuppose them. Supply chain development, for example, encompasses all other areas of work, as it aims at the integrated qualification of all supply chain structures against the background of a dynamic overall understanding (Göpfert / Wehberg 1995).

The intermingling of the different types of transformation expresses the system thinking of supply chain management. A design area influencing all variables is the configuration of the supply chain. The configuration strategy also defines much of the management's competitive room for manoeuvre. For example, 24-hour customer service is unlikely to be possible without an adequately decentralized spare parts logistics system. The configuration is also a particularly attractive subject of the S&OP as well as learning strategy of a supply chain. For instance, it determines the balancing potential of capacities and materials between sites amongst others.

3.3.1 Configuration

Networks of higher order

The configuration strategy of a supply chain characterizes the spatial arrangement of supply chain activities in their overall view. It goes beyond the mere warehouse problem, as it is not confined to the location of individual transshipment locations. On the other hand, for them the exact content design of the transshipment points, such as the equipment, conveyors, etc., plays a subordinate role (see for fine selection of individual micro-locations example Gaebe 1981, Lüder / Küpper 1983, and the warehouse Pfohl 1990).

If the theory of the general location factors according to Weber 1922 is taken up, a resource, work, consumption and transport-oriented configuration strategy can fundamentally be differentiated. The configuration in each case is being based on the relevance of cost factors and resources associated, such as labor, consumption, logistics, etc. (Schäfer 1980, Stahl 1994). In the following, the focus is on the **transport-oriented configuration** strategy. Of course, this does not wish to exclude the other factors altogether. Such a perspective, however, seems justifiable, as - in the context of competition considerations - it is in more and more instances the transport that causes particularly high costs and resource consumption. And thus, a transport orientation in the configuration of operational systems becomes more and more important in the future. In a way, digitalization can also reinforce this trend if the desired flexibility in the supply chain leads to higher transport volumes and resource consumption, and if the networks are not planned effectively.

In the course of digital supply chains, the configuration is much more flexible and distributed. The configuration is constantly in flux, in the sense of process orientation in the broader sense. Not the configuration as a whole, but individual objects (e.g. pallets, means of transport) undergo **continuous service improvements** (e.g. routes, cross-docking sites) in the course of a trial-and-error process. These are used as learning processes for the rest of the "swarm", so the other objects are passed. Anderson (2007) also points out that digitization is slowly reversing the "dictation of location" for the availability of products and replacing them in principle with "**markets without borders**". He speaks in particular of the decreasing transaction costs, increasing transparency of offers and omnipresence (ubiquity) of goods. Digital supply chains essentially support this development, and it is already observable today. For example, you can see this thanks to the rapidly growing market for courier and express services (CEP for short) due to e-commerce. It results in the trend of more delicate and flexible supply chain systems. And the discussed customer needs of Dawn Digital (Clay / Mashall / Glynn, 2017) do not leave any doubt that these trends apply to the broad portfolio of products as well as services in terms of mainstream consumption.

The form of the supply chain depends in this sense above all on two quantities, the number of nodes and their connections (for this and in the following Wehberg 1994). The **number of nodes** results from the amount of bearings in vertical and horizontal terms. In terms of vertical, this affects the number of storage levels, such as factory, central, regional and distribution warehouses. With regard to the horizontal, the number of bearings per stage is meant. In contrast, the **number of connections** involves the question of which nodes are to be connected to one another. A distinction must be made between vertical connections between different levels of storage and of horizontal connections between the bearings of a stage. The former should be realized, among other things, when skipping a storage level for service reasons, e.g. especially for delivery time, or seems appropriate from a cost point of view. The latter, for example, create the conditions for achieving equalization effects if they enable the transfer of safety stocks from one regional warehouse to another, even at short notice.

The combination of the above criteria leads to two polar configuration types, the **hub-spoke** systems on the one hand, which are centralized indirect connectivity arrangements and thus associated with stability-oriented supply chain structures.

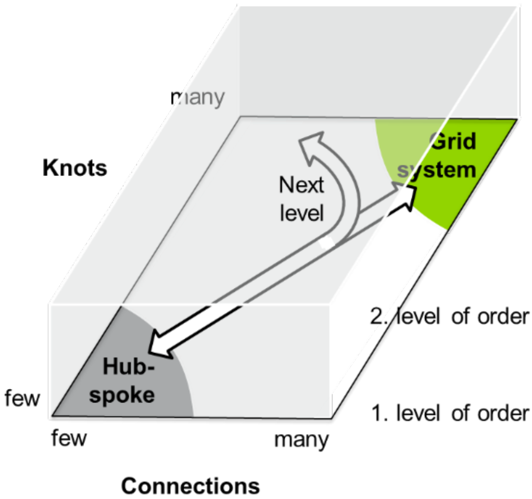
And on the other hand there are the **change-oriented grid systems**, which are decentralized configurations with direct connections on the other side (Figure 3.9). The high level of change in the grid systems results from the fact that the number and variety of supply chain relationships possibly used is comparatively high here. In particular, the complexity of supply chain planning brought about by the configuration assumes to be a higher degree. The positioning between the above extreme points can be done as a **multi-hub system**.

Historically grown supply chains often approach the grid system as they evolve. The increasing branching of the network then becomes more concrete in accordance with complex river systems. An initially unstructured networking is often the result. In such a situation, among other things, the performance-related arrangement of supply chain activities can justify longer processing times, higher working capital, limited transparency as well as the danger of strong fluctuations or instabilities. Vester (1980b) calls this form of development "**density-stress**" of a system. The supply chain is thus disturbed when the density stress occurs. The development, similar to a carcinoma, leads to disordered "**chaos**" if the supply chain is not being re-structured in good time by forming, if necessary, segment-specific, largely self-organizing subsystems or corresponding guard rails. Such a structured networking of highly complex systems is accompanied by the leap in supply chain **configuration to a higher level** of order, as illustrated in Figure 3.9. The connections within the subsystems are numerous. In contrast, the exchange between them is limited to comparatively few but intensive connections. The differences between unstructured and structured networking are becoming obvious (Gomez / Probst 1987, Wildemann 1994). In this sense, a digital supply chain aims for a higher order, which means highly complex but structured networks. Guardrails for network development can be used in this context. For example, such guardrails can be:

- Regional site clusters or regions that ask for special treatment,
- Listed freight forwarders or warehouse operators with distinguished performance levels,
- Prioritized customers or a list of dedicated clients that has been promised a special service level to,
- Certain products that rely on a dedicated supply chain network structure in order to keep its brand promises,
- Selected time frames such as holidays or weekends that operate differently,
- And generally, customized supply chain models and operating rules associated.

The self-optimization of supply chain operations, for example through algorithms, then moves within the limits of such crash barriers. Talking S&OP, the system will ask for management intervention, as soon such planed assumptions are not met. Based on respective alerts, the supply chain is then based on a management by exception, accordingly.

Figure 3.9 Change profile of the supply chain configuration



Incidentally, the higher order of configuration takes into account the trend and the necessity of keeping the division of labor of a value added system connected by a supply chain as close as possible (Hesse 1993). Especially the frequently propagated trend towards internationalization is critical here (Vester 1995). Next to the spatial order itself, the configuration of value-added activities thus has to be taken into account, which means cross-site integration. Both areas are closely linked. Therefore, the decision to integrate is to be seen against the background of the following goals (Liebmann 1991, Pfohl 1990, 1994):

- Minimization of transport costs on one side and storage costs (storage house and storage) on the other side,
- Realization of synergy effects and specialization advantages,

- Achieving an effective supply chain service (especially delivery time and flexibility),
- Tax optimization of international value added networks,

Strategies such as **geography postponement** (Bowersox / Closs / Helferich 1986), **bundling** and (de-) centralization can play an important role. It should also be noted that the subsequent success of a company's disintegration strategy depends largely on coordination with the value-added partner who performs the service. If the co-ordination of the two succeeds, Porter (1986) also speaks of "**quasi-integration**".

As an example of the integration possibilities between industry and trade, the following use case serves to optimize the goods receipt:

Project example: Goods receipt

Initial situation: Over the course of many years, a food retailing company had been pursuing a steady growth path first in Germany and later increasingly in European and, ultimately, worldwide foreign countries. Every year, numerous new stores were opened and connected to the supply chain network. In doing so, the company relied on regional distribution warehouses, which have two advantages in terms of distribution to the individual market locations: On the one hand, one avoids the acceptance of dozens of third-party deliveries from the various manufacturers in the markets. On the other hand, the provision of a broad article portfolio in the distribution warehouse - matched as closely as possible to the regionally varying consumption preferences of the customers - enables a short-term reaction to demand-related reordering of a market. In many cases, one to two "tailor-made" deliveries of one market per day can be ensured.

Objective: Over time, sales growth inevitably led to increasing inventory levels in ever-larger distribution warehouses, which the company has banned for particularly high-volume periods - such as high-volume storage. In the run-up to Christmas, for example, it was always possible to use it as an instrument in purchasing. In parallel with this volume growth, information technology also continued to evolve, and the company consistently opted for greater automation of its internal processes - from warehousing and picking to rolling stock inventory. Only with the delivery of the goods from the manufacturers - either with their own vehicle fleet or by means of their assigned freight forwarder - was there no satisfactory progress in efficiency over the years. At the end of the 2000s, productivity in this important step even declined and management had to react.

Approach: In the course of an investigation, it soon became clear that the company itself could not solve this problem by its own. The different suppliers encountered different requirements for all their competitors with regard to the loading of their goods, different product categories with different limits (eg "Food" vs. "Non-Food", "Cool" vs. " Dry ") and often-different delivery points for these categories within the warehouse location (e.g." Fruit always gate 7 "or "Non-food only on Tuesdays"). The warehouse operators increasingly installed "fully automated" goods receipts had to be operated by the delivering drivers with considerable time manually, which also did not work smoothly. A set of measures had to be put in place, which facilitated disposition and delivery for all participating market partners.

Result and digital relevance: As a result, the downtime of the delivering forwarders could be reduced from previously up to 4 hours to an average of 2.5 hours. At the same time, the companies involved reduced misconduct and damage during delivery, which resulted in additional cost reductions. The example also illustrates that an evolutionary, largely autonomous approach in several iterations and integration of upstream value-added stages can provide a good result, while the previous, isolated attempts of the retailer were previously inconclusive.

Success factors: A key success factor was the inter-company coordination of this important interface, so that the partners involved in the supply chain did not cause additional process breaks by individual optimization. The advantages of automated warehouse processes can now be consistently raised. The use of supporting IT, e.g. by a mobile accessible application for loading ramp management, also proved to be critical to success for the self-controlling approach.

City logistics

With regard to the interface between industry and trade, receiver-side bundling would be advantageous in many cases. In this context, city logistics is one example for doing so. The **origin** of the concept of city logistics comes from the need to minimize the environmental impact of urban traffic by **bundling transports** in and around cities and conurbations, as well as through intelligent networking, and to increase traffic efficiency and efficiency in general. Especially the retail trade in the inner cities has only a few storage options. High transport frequencies with often-low utilization levels of road vehicles are the result. The road and loading capacities in city centers are anyway limited. The delivery windows are usually limited to a few morning hours. Residents counter an expansion by overnight deliveries. The retailers do not desire an extension to the afternoon hours, because it is feared that supplier traffic hinders customer traffic. A corresponding cooperation between the carriers affected by this bottleneck promises improvements here, although at this point the line between cooperative and competitive relations should also be very narrow. However, the high degree of heterogeneity of the generally small-volume freight flows and in particular the previous bundling strategies (e.g. refrigerated, value-added, tank vehicles, services such as shelf management), do not always meet the goals of city logistics concepts and requires intensive coordination. In this context, digital supply chains offer new opportunities to organize intelligent logistics for the city. Closely related to the construction of such a city logistics is the establishment of freight transport and distribution centers at the periphery of the city. Originally, city logistics focused the **inbound** flow of retailers, accordingly.

Now, a next level of city logistics builds even stronger on autonomous transports and direct deliveries. Customers don't go in the city so much for shopping anymore but for entertainment and socializing if at all. Retailers and city shops have to meet these developing needs to stay attractive. At the same time, they have to strengthen their Internet presence, facilitate multi-channel contacts to end customers and connect these with their on-site offering in the outlet. A retail shop in the future is much more a show room, event and social platform than a supermarket or simple shop. Storage and shelves-space are becoming less important because products can be shown virtually but in an application context. The delivery can be direct from distribution centers to customers. For example, shops that are selling kitchens are not presenting cookers anymore but performing cookery courses and adventures or **experience worlds** associated. While building on the same network principles like the traditional concept, city logistics of the future considers more service aspects, focuses on the **outbound** logistics and is much more individualized for customers rather than customized to retailers only.

Many retailers think about this kind of city logistics in a way that they try to determine the best service provider and one-and-only transport network for the future. In an evolutionary perspective, however, there is no one-fits-all, neither an A-candidate of one top model. Rather, there is an on-going evolution of several transport concepts and thus several networks being part of the **retailers` eco-partner system**. A range of city logistics networks are being piloted, tested, scaled where viable and continuously improved. For example, crowdsourcing solutions for city logistics are evolving in many cities and there is a lot of creativity to market-enter city logistics as new crowdsourcing service provider.

Willingness to integrate

The extent to which potential benefits can actually be realized depends on the willingness of the value-added partners to support and implement the supply chain network patterns they have devised. Despite the high potential for success, the willingness of supply chain management to integrate, which means the extent to which the value-added partners agree to undertake or to give up certain functions of the overall supply chain, can vary greatly. Survey results on willingness to integrate, however, show that they are at a high level (Göpfert / Wehberg 1995). Restrictive it remains to be noted that the **expressed readiness** by no means must correspond to the actual.

The willingness to integrate knows many facets. Closely related to the integration strategy of the industry is, for example, the extent of the willingness to compromise in terms of delivery time (Göpfert / Wehberg 1995): The non-storability of supply chain processes (Rendez 1992), which means the synchronicity of service provision and use, requires that logistics capacities are to be provided in the amount of peak demand. The desired delivery time should always be met. Such a form of capacity planning, however, may entail competitive disadvantages if the capital commitment costs caused by uneven utilization are too high. Despite the fact that logistics services per se are not storable, the external factor, e.g. the product to be sent, can be stored. A temporal **balance between supply and demand** of logistical capacities and thus the smoothing of utilization peaks becomes possible. However, such an integration strategy on the part of the industry (it assumes warehousing tasks) presupposes an appropriate willingness to compromise the trade and subsequent value creation stages. In addition, a digital supply chain solves the need for scalable capacities and flexibility by outsourcing logistics services in a network to external third parties as required.

Tax optimization

Finally, the integration considerations of an international value creation network must take into account **tax and customs law** considerations. The first considerations are summarized under the heading "Tax optimized Supply Chain Management". In the past, international tax law made it necessary for the physical flow of goods to be as deep as possible in the country in which the company wanted to tax. In practice, this requirement sometimes led to goods being transhipped in one country only to profit from the tax benefits of that country. In contrast, tax law nowadays looks at the causal value creation, that is, it is not decisive where certain value-added activities are carried out. Rather, it is crucial who coordinates the value-added activities. For example, if a company's supply chain team is based in Singapore and gains five percent efficiency gains along the value and supply chain each year, these profits typically can be taxed in Singapore. The tax law thus fulfils the actual idea of supply chain management as a coordination task. However, given the potential loss of image in the case of public discussions of alleged tax evasion, many companies are reluctant to exploit these opportunities under tax law. In reality, this legitimate scope for tax law will probably play a role, above all, for globally active companies.

3.3.2 Transport

Mode and means of transport

The transport function marks the space bridging of goods (in the following Jünemann 1989, Pfohl 1990). With regard to the choice of mode of transport, it is important to build transport chains in such a way that the specific advantages of each mode are relevant. The advantages can be described above all on the basis of the criteria of transport speed and costs, as well as the environmental friendliness and networkability of the mode of transport. Of course, in terms of the systemic thinking of supply chain management, they are always to be seen in connection with the cost and service consequences of other areas. The weighting of decision-making criteria for the **choice of transport vehicle** is industry-specific, if not company-specific. Digital supply chains then map appropriate decisions of the mode of transport choice via suitable algorithms.

While, for simplicity, both the speed and the transport costs per tonne-kilometre increase from inland navigation and shipping, via rail and road to air freight, the corresponding energy consumption, and thus the environmental impact, tends to increase in this order. Of course, any cost advantages will only come into play if the corresponding minimum ranges are guaranteed and if the costs of transhipment can be neglected compared with transport costs. The speed of the carrier is not the same as the delivery or disposal time. Furthermore, the **networking abilities** of inland shipping, classic airfreight and rail are comparatively low. It depends on factors such as the locations of air, sea and inland ports, the course of inland waters and the rail network. In contrast, the main advantage of truck or road transport is usually its pronounced ability to form networks. He is thus highly suitable to meet individual transport needs in the area. Prospectively in the course of digital supply chains intelligent, thus self-controlling vehicles or truck drones increase the strength of this mode of transport. The automobile industry currently expects corresponding offers until about the year 2020. Analogously, ten Hompel (2014, translated) describes the following image of the future for internal transport: "swarms of autonomous vehicles take over (...) transport. The arrangement of workstations can now be changed at any time. The vehicles learn from each other. Their software agents negotiate orders and rights of way and constantly swap locations for new stations or warehouses. "

Current examples of the first self-steering vehicles are the Ray Park robot from Serva Transport Systems, Indego 1000 lawnmowers from Bosch, Container Shuttle from Altenwerder Hafen, F015 prototype from Mercedes, appropriate forklifts from Aberle and Still and the Bubble Car from Google (Heutger 2014). **Autonomous driving** can be considered as a mature technology so that its development towards being market standard mainly depends on regulation and acceptance. Intra-plant and high-way appliances are pilot areas, but autonomous transports are not limited to these.

It becomes clear that with innovation efforts, the **traditional boundaries** between modes of transport can shift significantly. Innovations such as maglev trains and the intelligent drones for the roads and, in the future, also aviation, promise to be able to redefine the performance characteristics for the respective modes of transport (ten Hompel 2014). Cost structures may also shift, such as inland shipping due to increasing fees for the use of artificial waterways. Moreover, other mega trends such as global warming impact transport modes as well. For example, the river Rhine in Germany is increasingly associated with transport risks for inland shipping, given the volatile water levels due to climate extremes.

The inclusion of different modes of transport in the form of the modal split for a transport chain takes the form of **combined transport**. A symbiosis of the different modes of transport means that all those involved in the transport process benefit from each other precisely because of their differences (Vester 1995). In contrast to the “broken traffic", there is no change of transport container during cargo handling in combined traffic. Its main aim is to combine modes of transport that are particularly suitable for the area with modes of transport whose advantages are used on the line. As basic forms of combined transport, hip-pack transport can be distinguished from container traffic. With piggyback transport one means of transport transports another. Examples of combined road-rail transport are the loading of entire swap bodies (Polzin 1995, for example), the so-called "rolling country road", where complete road-rail trains are transported by rail, and the roll-on roll-off waterway. In the case of container traffic, containers, for example ISO containers and lattice box pallets, are used to streamline the handling of the cargo (especially for the trucking of airfreight, Göpfert 1994).

In addition to combined transport, which means the successive switching of carriers, it may also be appropriate to provide different modes of transport in the form of different supply chain segments next to each other. The combined use of centralized and decentralized transport networks with appropriate modes of transport can then help to reduce transport costs while increasing supply chain services (Herron 1968).

The choice of **means of transport**, meaning the equipment of the fleet, is directly related to the decision for a particular mode of transport. In doing so, the choice of means of transport will always be measured by the quality of the selected vehicle, which generally reflects the degree of fulfilment of certain requirements imposed by certain stakeholder groups of logistics, primarily consumers (on the quality term Pfohl 1992). Above all, the following five criteria determine the quality of the means of transport:

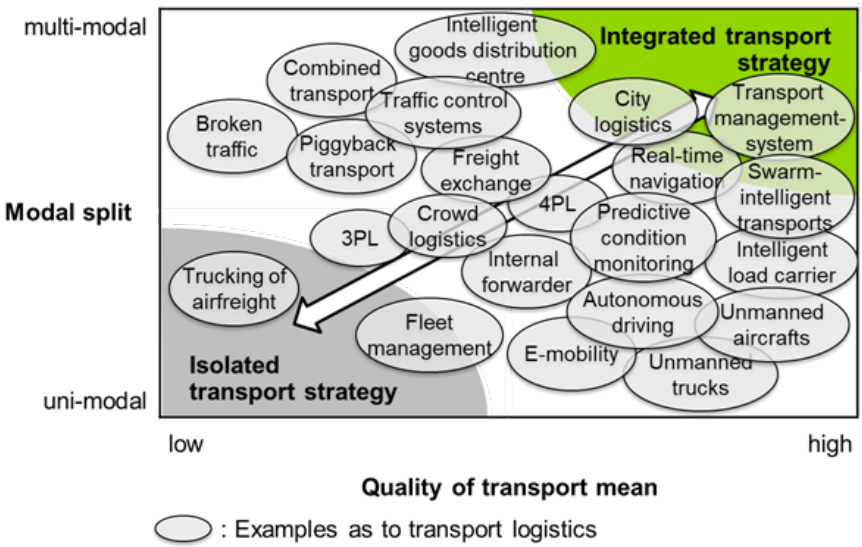
- Transport security,
- Technical equipment,
- Human factor as well
- Drive technology and fuel.

In the course of digital supply chains decisions are made autonomously, like the products themselves decide on their packaging, the packaging on their transport containers, the transport containers on the means of transport, and the latter on the transport route. Everyone involved has access to the relevant information about a cloud. The future **transport organization** thus is recursive, semi-autonomous, redundant and self-referential. Transport management in this case is focusing on managing exceptions as well as determining the right (meta-) algorithms that facilitate the learning of this kind of autonomous decision-making. There are hardly any truck driver anymore, and hardly any transport planer. But there are supply chain experts that design the transport system by applying both their deep expertise in transport management as well as technology associated.

Integrated transport strategy

Depending on the modal split and the quality of the means of transport, two extreme basic patterns of transport can be summarised: integrated transport and isolated transport (Figure 3.10). The **integrated transport strategy** enforces multimodal transport chains within the framework of change-oriented logistics structures on a high quality level of intelligent means of transport. The combination of transport modes and the consideration of quality requirements of certain stakeholder groups leads to potentially multi-layered state forms of the system of transport logistics. Integrated transport corresponds to the characteristic of digital supply chains insofar as it best promises to meet its flexibility requirements on the transport side. It is only through the use of cyber physical systems that a far-reaching networking of means of transport (vehicles, transport participants) and traffic infrastructure is made possible and allows, for example, traffic accidents to be prevented and environmental protection to be improved. This means that the systems communicate permanently with each other, for example in actual time, information about the weather, the traffic situation or the availability of traffic infrastructure. Cyber physical systems play a central role, especially in electro mobility, as they enable efficient battery and charge management (acatech 2011). The **isolated transport strategy**, on the other hand, is limited to uni-modal transport with moderate means of transport quality. It takes place in more stability-oriented structures of logistics management.

Figure 3.10 Change profile of the transport strategy



The following project example shows the importance of the quality of the means of transport and how to ensure it.

Project example: Internal forwarding

Initial situation: At the production sites of an international company in the raw materials industry, the supply and disposal activities of the production and maintenance facilities at the respective location have grown over the course of time and have been independently managed and carried out. In particular, the internal transport of raw materials, auxiliary materials and operating supplies to the departments as well as the disposal of recyclables and residues were the responsibility of the companies at each individual site. In the course of time, all plants had purchased their own transport equipment optimised for the specific requirements, trained production and maintenance personnel for these activities and integrated the transport organisation into the processes of the respective plant. As a result, the energy effects of planning and carrying out transport activities at one location could not be systematically exploited due to decentralised control and the transport services of the locations could no longer be compared with one another. In addition, potential could not be achieved by standardising the equipment. There was already a lack of sufficient transparency regarding transports, transport requirements and the corresponding use of resources.

Objective: The company management did not want to accept this situation any longer, especially since a comparison with other international companies in the raw materials industry had shown that these companies had organised their internal transport activities centrally with greater success. The company therefore set itself the goal of increasing its cost-cutting potential.

Approach: The conversion of the decentralised organisation of internal transports to the central organisation was implemented in four phases. First, all transport services provided by the respective units of the locations were recorded as part of an as-is survey. A concept was then developed as to how an "internal freight forwarder" should provide the transport services of the respective location in the future. The core of the concept was the use of cross-location transport management software, which was to ensure the transparent recording of transport requirements, the processing of transports and the invoicing of transport services according to the polluter-pays principle. In the next phase, the feasibility of the project was first demonstrated on the basis of a pilot location and then the concept was rolled out to the other locations. Once the concept had been implemented, the transport equipment could be standardised and the transport personnel specialised in further optimisation steps. Outsourcing freight forwarding tasks was conceivable in the medium term.

Result and digital relevance: As a result, the implementation of the "internal freight forwarding" project showed an increase in efficiency of 18 to 23 percent, depending on the location. In particular, the current transparency of transport requirements reduced the proportion of empty runs and achieved synergy effects in the bundling of transports to production and maintenance operations. Bidirectional transports between the warehouse and the respective area were replaced by transport networks. In addition, the equipment has been standardised and the useful live cycles of the respective equipment have been considerably extended. The project was a good example of the potential of avoiding homemade complexity in transport equipment, how it can be harmonized through standardisation, how complexity can be better managed and how it can contribute to more (internal) customer orientation and flexibility in transport logistics. The support of the internal freight forwarder by modern transport management software and a perspective platform enabled a stronger self-organization of the control in the sense of a digital supply chain in the medium term and the scalable integration of external transport companies as required. It also simplified the use of electro-mobility through networked battery and charging management.

Success factors: It was crucial for the success of the project that the support of the company management was available in every phase of the project. In addition, the fears of those responsible for production and maintenance that the switch to central control of internal transports could have a negative impact on the performance of their operations could be countered by early inclusion in the planning of the project. In particular, great importance was attached to the selection of the pilot location. In the optimisation phase following implementation of the concept, the consistent measurement of KPIs with the resulting derivation of savings potential was decisive for increasing efficiency.

Freight transport centres are a core component of bi- and multimodal transport chains. They are increasingly being assigned a leading role. In the following, they will therefore be dealt with separately and briefly.

Freight transport centres

The concept of the freight transport centre (in German: GVZ) includes the consolidation of different modes of transport at a conveniently located hub of the logistics system (e.g. Hesse 1993 b, Seufert 1992, Wiedemann 1993). Freight transport centres generally take on the function of a **goods distribution centre** (German: GVtZ), especially in connection with city logistics concepts, which forms the interface between local and long-distance traffic (Kracke et al. 1994). The central advantage of such freight transport and distribution centres is that they lead to a "**linearisation**" of the transport connections when additional source and destination points are included in a supply chain system. While in situations without such nodes an exponential increase of traffic connections can be observed, the latter in the case of such transhipment facilities behave proportionally to the number of new source and destination points to be included. Although at first glance the impression may appear to arise, freight transport and distribution centres are by no means necessarily linked to a hub-spoke logistics strategy. They can, for example, justify such a configuration at the first order level of the supply chain. At the second level, however, supply chains can be structured in the form of a grid system.

De-materialization and 3D printing

The more efficient design of transport flows must be separated from their substitution by the increased use of only information flows. Transport avoidance takes the place of transport control. This so-called **de-materialisation** of logistics processes offers great potential for increasing efficiency (e.g. Schmidt-Bleek 1994). Intangible transport can replace material transport. Examples include "teleconferencing" and "teleworking", in which company employees work at home on their PCs (Höller 1994). The combination of "Home" and "Office" then becomes the so-called "Hoffice", so that occupational traffic is avoided.

Another example is the so-called **3D printing**, also known as additive manufacturing. In this process, three-dimensional workpieces are built up in layers (e.g. Gebhardt 2002, Fastermann 2012). Production is computer-controlled from one or more solid or liquid materials according to predefined dimensions. During production, physical or chemical hardening and melting processes take place. Typical materials for 3D printing are plastics, synthetic resins, ceramics and metals. The most important techniques of 3D printing are:

- Selective laser melting and electron beam melting for metals,
- Selective laser sintering for polymers, metals and ceramics,
- Stereolithography and Digital Light Processing for liquid synthetic resins as well as
- Polyjet Modeling and Fused Deposition Modeling for plastics and partially resins.

Combined printing processes working with different materials are increasingly being used. Important advantages over conventional manufacturing processes lead to an increasing spread of 3D printing also in series production. Compared to the injection moulding process, it has the advantage, among other things, of eliminating the costly production of moulds and their changing. Some very complex moulds can be produced, which cannot be reproduced with classical manufacturing processes. Compared to all material-removing techniques such as turning, cutting and drilling, 3D printing has the advantage of eliminating material loss. In many cases, 3D printing is also more energetically advantageous because the material is produced directly in the required dimensions. Last but not least, 3D printing allows significantly faster development times through prototyping.

The possibility of setting up 3D printers more demand-oriented or more decentralized offers a considerable de-materialization potential for transport logistics and can influence all stages of the value chain. However, due to the - depending on the technology - sometimes considerable machine costs, the overall manufacturing and logistics costs must be optimized. For manufacturers and logistics service providers, this offers opportunities to introduce new value-added services and business models. For example, so-called "**Fabbing Shops**" offer 3D printing as a stand-alone service, similar to copy shops. And system manufacturers can, for example, move backwards in the direction of parts suppliers if they print important parts themselves. With increasing learning and scale effects at the printers themselves and their production, the opportunities to optimize value chains on the basis of additive manufacturing and to develop new business models will grow, especially in the maintenance, service and spare parts business. The possibility of an economical production of **batch sizes N=1** corresponds not least to the flexibility concept of digital supply chains. The efficiency effects of each dematerialization, however, depend on the exact pattern of technology use and must be evaluated concretely in each individual case.

Many companies outsource their transport logistics to logistics service providers or forwarders. The strategic purchase of such transports often offers considerable potential because the complexity associated with the transport services is not handled effectively. The following project case shows the possibilities of simulations and outlines the self-organized purchasing process in the course of digital supply chains:

Project example: Purchasing of transport services

Initial situation: In the past, a company in the Manufacturing segment had outsourced its distribution logistics to various service providers. In order to simplify the allocation process, the purchasing manager defined 5 regions, for each of which a "top dog" forwarder was selected. In addition, there were historically grown business relationships with over a dozen forwarding agents. The purchasing manager justified this approach by stating that it was not possible to compare around 50 forwarders on around 200 individual routes, especially as many providers made their prices for selected routes dependent on paired traffic elsewhere. In addition, they had had good experiences with many forwarders and did not want to take the risk of changing suppliers. In a rather random comparison of freight rates, however, the company found that the selected forwarders did not necessarily always offer competitive rates when comparing individual routes.

Objective: The company aimed to review the purchasing process for distribution logistics (full truck load) and, where possible, achieve further savings. The service was to remain unaffected, which means the company did not want to achieve any savings by worsening the service level.

Approach: In the course of strategic purchasing, a digital RfP process (Request for Proposal) was set up and the addressable purchasing volume defined. More than 50 service providers were requested to submit offers. The basis was around 200 routes of the distribution network in line with the company's strategy. The specification of premises for pricing or links in the form of paired transports was permitted. Around two thirds of the invited forwarders had submitted bids, with at least three proposals for each route in order to ensure a market comparison. Against this background, the coverage of the routes and consignments was over 99 percent in each case. On the basis of the bids submitted, alternative allocation scenarios were calculated using simulation procedures. For example, the proportion of long-established and proven forwarders played a role. The preferred scenario provided the basis for negotiating the offers with the selected forwarding agents.

Result: The company was able to realize savings of 11 percent on transport costs. One third of these savings were due to intermodal transport and thus supported the company's sustainability strategy. However, more than half of the freight forwarders had to be replaced because the offers of the providers who had been active so far were disappointing in some cases or even not available for many routes. All in all, the number of integrated forwarders could be reduced from 17 to 12.

Success factors and digital relevance: Decisive for the success of the project were the development of allocation scenarios and the corresponding simulation algorithms. This made it possible to take paired traffic and the strengths of individual providers into account. While the simulation and awarding of contracts in the outlined case study were controlled centrally by the project team, the algorithms provide a basis for steering towards the overall optimum again and again in the course of future, self-organized negotiation processes between decentralized units. In this respect, the case study also stands for the use of intelligent procurement rules for transport services in the digital supply chain.

Packaging logistics is closely related to the use of transport logistics in general. Exemplary packaging strategies are therefore presented in the following.

3.3.3 Packaging

Functions of packaging

Packaging is the separable wrapping of a good, the packaged good (Koppelmann 1979). The functions of packaging are manifold (hereinafter Jansen 1987). Ultimately, they reflect a requirement profile that is placed on them primarily by logistics and marketing, and in which supply chain management must bring about a suitable compromise. The **marketing-induced requirements** of packaging include the sales function, for example its function as an information carrier and differentiation instrument, as well as the use function, for example how the packaging can be closed. The **logistic-induced requirements** include transport ("underrideable, non-slip"), storage ("stackable, manageable") and protective ("impermeable") functions. The starting points of a logistics-compatible packaging design are logically primarily directed towards transport packaging (Baumgarten 1972), while the starting points of a marketing-compatible design are more likely to be product packaging.

Now the use of **transport packaging** is at least partially substitutive to the emergence of product packaging. For example, elaborate product packaging designed to protect the product can be made more economical in terms of material consumption by adequately designing load carriers. Moreover, in individual cases it is even possible to completely dispense with industrial product packaging if, for example, consumers use their own household packaging for milk or butter (which is not always harmless for reasons of food law). The same applies to some packaging designs initiated for marketing reasons, such as high-gloss packaging (Luttmer 1993). The disposal of transport packaging is also more a matter of logistics control than of product packaging. In Germany for example, many companies have already solved the problem of the disposal of product packaging by participating in the Dual System Germany (DSD). According to § 6 of the German Packaging Ordinance, industry and trade are obliged to take back transport, repackaging and consumer packaging and to recycle it. Alternatively, they can participate in a nationwide system such as the Dual System Germany (DSD), which guarantees regular collection and achieves certain material-specific collection rates.

This does not mean that marketing-induced requirements no longer play a role against the background of competitive considerations. **Product packaging** can support the positioning of a product as a brand offering. And the importance of marketing packaging requirements for logistics can also be seen when, for example, special attention is paid to the ease of disposal of product packaging within the scope of the application functions. Moreover, certain marketing-induced requirements cannot be ruled out, for example for reasons of food law (Boykov 1989). This is true although the trend of making products smarter with means of digital technology can reduce the requirements towards product packaging to a certain extend. For example, information requirements can also be met via suitable information terminals or mobile devices that access the Universal Product Codes (UPC) or Quick Response (QR) codes of the products.

At the end of the day it is not an either or, but rather always a question of a possible shift in the focus of logistics with regard to the fulfilment of its functions. Conversely, the close linkage of the marketing and logistics-induced tasks of packaging also places certain demands on the design of the packaged goods or on the product policy of marketing.

Standardization and postponement

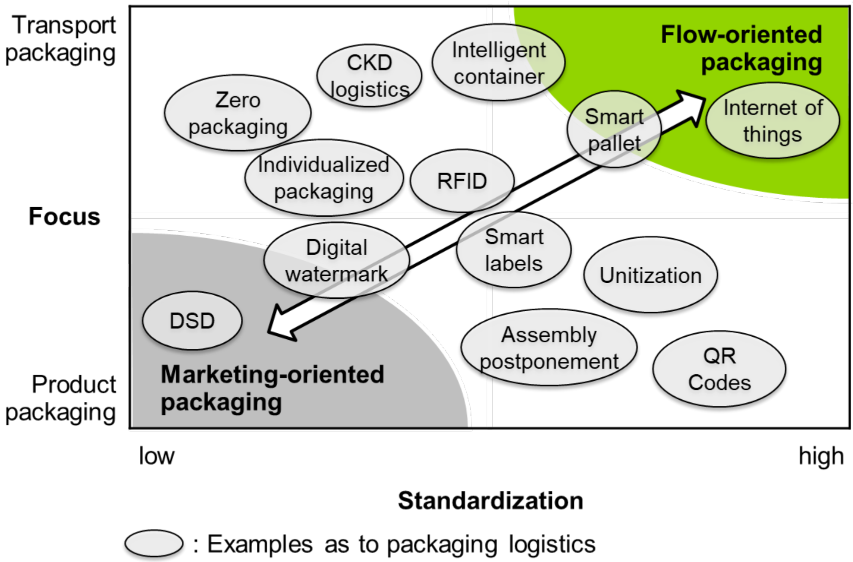
The formation of logistic units, **unitization** (Pfohl 1990), is closely related to the logistic design of packaging. Both from an ecological and an economic point of view, it is helpful to combine individual packaged goods into larger units when storing, handling and transporting goods. Ideally, the transport, storage, ordering and loading units, etc., should be the same. (Bahke 1976, Böttger 1991). The summary of larger sales units, for example the "Ocr-Pack" and the use of pallet loads as secondary placements, can also have a sales-enhancing effect. As a rule, logistics units are set up within the framework of appropriate standardisation and make it necessary to coordinate companies at different stages of the value chain. The harmonisation of several packagings in the form of **modularisation** - as a special form of standardisation - is necessary when two or more companies with different packaging sizes work together in parallel in a transport chain. Examples of standardised units in packaging logistics are pallets and containers (Michaletz 1994).

Closely related to the standardization of packaging materials is the standardization of the packaged goods themselves. In particular, the links between the packaging system and the company's postponement strategy, here the AssemblyPostponement (Bowersox/Closs/Helferich 1986), must be considered. The **Assembly-Postponement** aims to integrate those value-added activities that differentiate the products into the logistics chain as far as possible. This endeavour is in line with the desire to use certain packaging standards across large parts of the supply chain. On the other hand, the marketing-induced differentiation measures, albeit "late", conflict with the standardization efforts of supply chain management. Different products often require different packaging. And the ongoing individualization of products as a result of many digitalization strategies makes the need of balancing between standardization and differentiation even more relevant.

Flow-oriented packaging strategy

In summary, the typical and basic patterns of packaging logistics can be presented on a spectrum with the following two poles: **Flow-orientated packaging** strategies attempt to realise logistical requirements in the form of value-added stages of comprehensive standards. Horizontal cooperation enables the standardisation, modularisation and networking of intelligent packaging materials, especially in the areas of transport, handling and storage. The coordination of the packaging logistics of the company under consideration with the other supply chain functions makes it clear that the flow-oriented strategy corresponds with change-oriented structures and a digital supply chain in particular. In many cases it is only possible through cooperation with upstream, downstream and secondary logistics stages at all. And in particular the assembly postponement often associated with the flow-oriented strategy ultimately creates the prerequisite for a higher degree of complexity of the entire system, which becomes obvious, for example, in the form of the high product variety that can be handled by supply chain management. In contrast, **marketing-dominated packaging** strategies aim to implement corresponding differentiation efforts, especially in the area of product packaging. The dominance of marketing can lead to the fact that logistical requirements are often seen as a restriction and not as an opportunity. External relations, which speak for a flow-oriented design of the packaging system, remain largely unconsidered. Corresponding strategies are therefore based on stability-oriented logistics structures (Figure 3.11).

Figure 3.11 Change profile of packaging logistics



In individual cases it seems quite conceivable that in the medium term the development of product packaging that has just been presented may become obsolete. Even though the complete obsolescence of packaging will seldom be depictable, considerations aimed at "**zero packaging**" can provide creative impulses for packaging avoidance and thus prevent too much packaging, so-called "overpacking", by limiting it to what is functionally necessary (Hopfenbeck 1991). Such efforts to achieve savings can, of course, be exaggerated if, for example, the stackability of transport packaging is sacrificed in favour of thinner packaging materials or the protective function is abandoned (Frerich-Sagurna 1993, Luttmer 1993).

RFID and the Internet of Things

In the sense of flow-oriented packaging strategies, it may be appropriate to support the control of flows of goods at the level of the individual packaged good through the use of suitable information and communication technologies. Transponders or control chips can be attached to the individual transport and product packaging to enable transparency or even decentralised control.

Radio Frequency Identification (RFID), for example, offers transparency and traceability by automatically reading out certain product information of a packaging that is then uniquely identifiable via radio waves. It can be understood as a preliminary stage to the use of cyberphysical systems. However, such identification of objects can also be carried out using barcodes or 2D codes. "In the field of goods transport logistics, RFID has established itself as a passive technology for identification, localization and status determination. Up to now, however, these systems have only been able to determine the positions of goods comparatively inaccurately and to update their status only very rarely. The use of cyber-physical systems in supply chains with intelligent, active objects offers opportunities for new applications, such as continuous position tracking and status queries in real time, and opens up new possibilities for planning and controlling deliveries (acatech 2011). Devices such as **sensors and actuators** extend the functionality by the registration of states or the execution of actions. Through the use of cyber-physical systems, the "RFID-based Internet of Things (...) gets eyes, ears, arms and legs" (ten Hompel 2014, translated).

Cyberphysical systems embed software technology in the packaging and connect it by means of a communication platform in an internet-like structure. This technology is also discussed under the heading "**Internet of Things**", because it links the real objects, here the packaging, with a virtual image and thus gives them the opportunity to control themselves. Initial applications of such packaging systems include the intelligent "smaRTI" range, the intelligently networked "DyCoNet" container and intelligent "inBin" containers (ten Hompel 2013 and 2014). The term "Internet of Things" goes back to Kevin Ashton in 1999. The goal of the Internet of Things is to close the gap of information between the real and virtual world. It is a core component of digital supply chains because it enables decentralized control of highly complex supply chain networks.

If packaging cannot be avoided, appropriate disposal is required. However, before the strategies of disposal logistics are discussed, the behaviour patterns of warehouse and information logistics are discussed.

3.3.4 Warehousing

Functions of warehouse

Warehousing logistics contains all the information relevant to the amount of warehouse stock. **Stock** levels can be understood as the buffer between input and output of two downstream supply chain processes, which arise as soon as the two processes differ in time (Tempelmeier 1983). They always arise, for example, when more economical batch sizes are to be used in production, procurement and logistics. Furthermore, they arise when, for example, speculations are made about the scarcity of certain goods, whereby the scarcity can result both from economic (procurement prices) and ecological (scarcity of natural resources) correlations (Pfohl 1990).

Overall, inventories can be traced back to two central factors: Firstly, they are the result of the **lack of synchronisation** of quality flows, more precisely of the output of one river and the input of the other. Even when management is fully informed, technical and organisational inconsistencies often stand in the way of a complete coordination of the processes, in addition to the economic reasons just mentioned. In this context, stock levels are partly intended, but are generally understood as an expression of insufficient process orientation in the narrower sense (behaviour in the system). In this form they are the exact part of everything "flowing", which at first makes their existence appear unsatisfactory (similar to KroeberRiel 1966). In particular, they stand in the way of short processing times. On the other hand, stocks are partly to be seen as "**slack**", i.e. as the result of a lack of controllability of supply chain processes. They are then the result of uncertainties in mostly downstream and upstream process stages and the result of more or less existing process orientation in the broader sense (behavior of the system). Corresponding imbalances can be attributed to demand booms, traffic jams, smog bans and machine failures, for example. Last but not least, inventories in the form of queues can also be economical. In this context Erlang (1909) lays the foundation for a **theory of queuing** which was further developed in the 20th century in the course of operations research. In summary, warehousing tasks are always a function of the system complexity of supply chains.

Brook-bed model

Against the background of the complexity management of supply chains, the tasks of warehousing can be illustrated using the so-called brook-bed model (similar to Kummer 1992, Stahlmann 1988). In many companies the insufficient process orientation is obscured by stocks. Since the patterns according to which the supply chain behaves are not recognized and also the most extensive synchronization of the processes fails, one helps oneself by compensating the lack of supply chain competence by comparatively high stocks and the associated storage costs. Not the actual problem, the lack of knowledge of the system behavior or the processes running in logistics, but only its symptoms, namely uncoordinated and unforeseen stock calls, are dealt with. In real terms, however, the high level of confirmation only intensifies the problems arising from the inadequate process structure. Thus, high inventories are accompanied by long processing times, which lead to further planning horizons and thus to even greater uncertainty (e.g. Wildemann 1994). In this context we can also speak of an **ambivalent control loop** for storage.

In such a situation, it is above all the reduction of the stock level that shows the bottlenecks and discrepancies. In the course of the inventory reduction, it also becomes clear which inventory level can be attributed to a lack of synchronisation of the processes and thus can usually be reduced and which share can be attributed to uncertainties regarding the system behaviour. The goal must then be to determine the type of "un"order. Typical **sources of disturbance** in the supply chain have to be identified in order to be able to initiate its process-oriented handling. Behavioural patterns for logistics and warehousing in particular must be conceived which counteract the disruptive factors identified in an appropriate manner and, above all, reduce the dispersion of stocks attributable to them. Inventory reduction thus functions as a means of perceiving complexity. At the same time, inventory reduction presumably raises a multitude of conflicts between different areas of the company, which were previously covered by the high inventory level and the associated complexity negation or "rape". It can thus be used as a conflict driver, so to speak.

These remarks made clear the position of the warehousing function in the course of the horizontal, which means along the supply chain, and the resulting functions (also Thonemann 2010). However, the warehousing tasks are also geared to the goods program to be served by supply chain management. For cost reasons, their differentiation in the form of differentiated, **selective warehousing** may seem expedient. As is well known, the essential selection criteria for warehousing are the demand structure of the goods (RSU) and the ratio between the quantity of the goods to be stored as well as the sales and procurement volume attributable to it, ABC (Grochla 1978, and continuing Bowersox/Smykay/LaLonde 1968, Stahlmann 1988). These are being sumarized by supply chain models, accordingly. The use of cyberphysical systems in the sense of a digital supply chain can be helpful because it helps to recognize relevant behavior patterns of (semi-)finished products and to sharpen them over time. This leads to a **dynamic understanding of selective warehousing** which builds on alerts or early warning signals to adjust stock levels where possible. Algorithms thus are flexibly adjusted with means of meta-algorithms.

Too much differentiation in warehousing according to the goods it holds can, however, lead to the savings it achieves, for example through lower capital commitment costs and insurance premiums, being overcompensated by the additional expense of the now more complex disposition. In this context, **automatic data processing and self-control** in the sense of a digital supply chain can be decisive for the economic use of a differentiated strategy. In this respect, selective warehousing always requires a comparison with rather undifferentiated, flat-rate warehousing. The more or less differentiated control of warehouse stocks is one of the basics of complexity management of supply chains and digital supply chains in particular. Depending on the sector and size of the company, some of them find it difficult to manage selective warehousing, dynamically, because they lack a robust approach and methodological knowledge. Let`s therefore discuss a project example for a basic optimization approach:

Project example: Inventory optimization

Initial situation and objectives: A company in the manufacturing industry with a global production network and worldwide supply relationships between locations found that its working capital was comparatively high on the basis of the published annual financial statements of its main competitors. The company was not conclusive as to the extent to which the figures were due to structural differences between the companies and as to how the causes were distributed among the areas of outstanding receivables, liabilities or inventories. In addition, the share of quick orders increased, leading to significant disruptions in the supply chain, especially in production. For this reason, the company launched several projects, including inventory optimization.

Approach: The inventory optimisation project was divided into four phases. In the first phase, the current supply chain relationships in the production network as well as inbound and outbound logistics were structured in the sense of baselining and the basic inventory data collected. In the second phase, the products were segmented from a supply chain perspective (volume, niche and occasional products) so that, for example, products with a high volume and uniform demand were combined. As an alternative to the current division of labour between production sites, new scenarios were developed, such as the concentration of all occasional products with low volume and volatile demand on selected production sites and roads. On this basis, new target inventories were determined both by internal benchmarking per product segment (top down) and by analytical extrapolation of target inventories (bottom up).

The third phase focused on the adjustment of inventories, with the company holding transitional buffer stocks in certain product areas as a safety measure. Parallel to the adjustment of the confirmation to the determined target level, selected suppliers and customers were addressed with regard to their willingness to take over certain stocks on their part or, if covered by the company, to take this into account in pricing. In the fourth phase, the now optimised approach to inventory optimisation was permanently anchored as a process and responsibility was transferred back to the line in order to prevent the optimisation effects from being unsustainable as a one-off exercise.

Result and digital relevance: As a result, inventories were reduced by more than 12 percent on average and by up to 85 percent in selected product areas. By introducing a proper segmentation and integrating customers and suppliers, inventory management processes were referenced and expanded. The resulting improved controllability of the value-added chain offers the possibility of anchoring self-control mechanisms in the sense of a digital supply chain using suitable algorithms. If demand patterns change or new products have to be added, inventory management itself can be further and continuously optimized in this case.

Success factors: The following three factors were decisive for the success of the project: First, the holistic optimization taking into account alternative division of labor between the production sites. Second, a robust methodology that combines the "top-down" view in the form of internal benchmarking with the "bottom-up" view in extrapolation. And thirdly, the permanent anchoring of inventory optimization as a self-organized process in the company, so that a sustainable inventory reduction could be implemented.

In addition to the decision facts of the warehousing logistics mentioned here, the so-called just-in-time will be examined in more detail in the following.

Just-in-time

Just-in-time (JIT) is a delivery concept originating in Japan. It is understood in the sense of a timely delivery. It is often equated with Kanban, but in addition to the product area it also refers to procurement - **JIT procurement** - and distribution - **JIT distribution**. The exact timing of the supply is not an end in itself. Rather, it requires classification into the supply chain and corporate goals. Just-in-time is therefore concerned with achieving a high level of reliability and delivery flexibility and reducing the capital commitment costs caused by warehousing. It thus makes a contribution to the company's **market orientation**. On the other hand, Just-in-time must be applied along the entire supply chain if it is to achieve the goals just mentioned. Due to the broad significance of this concept, the just-in-time (planning) philosophy is also spoken of, which generally attempts to increase added value through the punctual delivery of objects, especially goods, and the associated design concepts. Such a JIT philosophy is an expression of a high level of competence in supply chain management as well as a high level of integration of intra- and interorganisational processes. It is supported by a digital supply chain, which means in particular by the use of cyberphysical systems with their possibilities of self-control. At the same time, it requires a minimum extraversion of supply chain management.

The JIT philosophy has also been criticized many times in the past because fundamental **disadvantages** are associated with it. In this context, the following is cited above all:

- JIT delivery by rail or inland waterway is not possible because the throughput times on these modes of transport are often too long and the reliability and flexibility are often inadequate (Vester 1995).
- Due to the smaller transport lots in the course of the JIT, the transport frequency and thus the total traffic volume increases (Blamauer 1992). The proportion of empty return journeys is increasing. Also the shift from a little heavy to many small vans is, despite the initially higher utilization of the individual vehicle, at least from an ecological point of view rather a disadvantage and leads to the fact that the road is converted into a "main warehouse" (Atteslander 1987). In addition, transport safety is reduced due to the often adopted 'fire brigade function' of JIT in the event of failures in delivery (Thaler 1990).
- The advantageous implementation of JIT is increasingly countered by the so-called "transport time syndrome" (Reese 1993, Zäpfel 1989). Due to the increase in disruptive factors, delays occur for the first time. As a result, in addition to the usual call-off quantities, which are calculated on the basis of usual calculations, further orders are placed in order not to disrupt the flow of value added. This type of behaviour can then lead to longer delivery times and once again earlier call-offs of deliveries as a result of the increased transport volume that this tends to entail. The advantages of JIT can therefore be overcompensated.
- In addition, there are supposed disadvantages that result from the departmental thinking of some practitioners and are partly characterized by comparatively emotional and generalizing arguments (e.g. Hahn, 1991).

However, these criticisms of JIT are relativized when one realizes that:

- The problems of multimodality are by no means due to the JIT system itself. On the contrary, the lack of reliability and flexibility of the railways is a temporary problem, without the use of this mode of transport also appearing suitable for JIT. In the course of the multimodal design of the JIT transport chains, freight transport and distribution centres can then also be integrated and corresponding bundling effects achieved (Fischer 1993, Reese 1993). The long transport times of rail and inland waterway transport do not contradict the JIT philosophy. High transport times and punctual deliveries do not fundamentally contradict each other (Hesse 1993). Empirical results show that a large number of companies can also live with higher delivery times in the course of JIT than the 24 hours already established in many places (Göpfert/Wehberg 1995).

- The JIT discussion is often based on a too narrow understanding of the term. Transport frequencies, lots and degrees of capacity utilization are then put at disposal ceteris paribus. It is not recognized that a holistic introduction of the JIT philosophy along the entire supply chain does not treat the production, storage and transshipment locations of those involved as a constant. Rather, the introduction of so-called JIT warehouses, which means buffer warehouses close to the transport sinks, and the establishment of value-added partners, e.g. suppliers and manufacturers close by, make it possible to adapt the overall configuration and also avoid the disadvantages of the transport time syndrome described above (Spelthahn et al. 1993). However, the former solution, the JIT warehouse, contradicts the JIT philosophy to the extent that the latter is aimed precisely at avoiding warehousing (Zibell 1989).

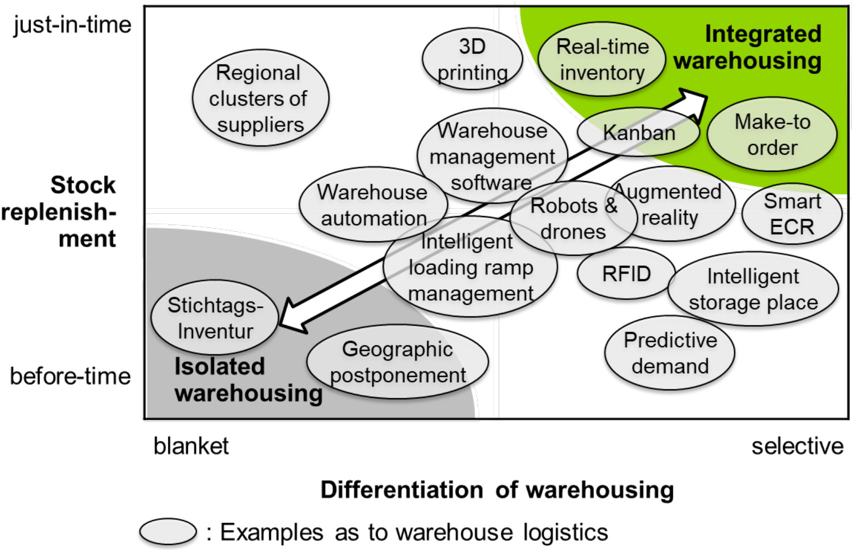
Overall, therefore, it is not possible to make any generally valid statements about the **advantages** of the JIT philosophy. It depends on the individual case specific design of the concept idea. In individual cases, a "Before-Time" (BT) could therefore prove to be more advantageous, which means the deliberate admission of intermediate storage. An exaggerated emulation of the JIT idea is also hindered by the fact that it requires a certain minimum control over the supply chain, which can often be called into question due to corresponding disruptive factors.

Integrated warehousing

The summary of the above behavior patterns leads to two extreme system strategies of warehouse logistics, as shown in Figure 3.12. A distinction must be made between **isolated warehousing** and integrated warehousing. Due to uncertainties, management's lack of process orientation or other factors, isolated warehousing is forced to maintain comparatively high inventories. The differentiation of warehousing with regard to certain selection criteria is dispensed with. JIT principles are not applied. The degree of system complexity is therefore comparatively low. In toto, isolated warehousing logistics corresponds to stability-oriented structures. In contrast, **integrated warehousing** impresses with a high degree of differentiation of the goods to be served by it in the form of selective warehousing. Wherever possible and advantageous, process chains are coordinated just-in-time within the framework of changing logistics structures. The integrated warehousing can also be supported by the possibilities of digitalization in the form of cyberphysical and self-controlling systems, as a basis for selective warehouse management and JIT. Intelligent, self-controlling threats, for example, carry out storage and retrieval processes as well as inventory management decentrally.

The close connection between JIT and selective warehousing or BT and flat-rate warehousing is due, among other things, to the fact that only in the rarest of cases is the entire goods program of a value-added system just-in-time-capable (Zeilinger 1987). JIT-capable are in particular AR goods. The high supply chain competence, which is a prerequisite for selective warehousing, also supports the establishment of JIT and vice versa. In this respect, JIT and selective warehousing together form the core components of integrated warehousing. Furthermore, driving an integrated warehousing strategy requires precise knowledge of the demand structure as well as qualified information logistics in general.

Figure 3.12 Change profile of the warehousing strategy



The complexity of the warehousing strategy is mainly derived from the possible conflicts of objectives such as delivery reliability and capital commitment. In addition to classic inventory optimization, the Supply Chain Finance concept can offer additional target contributions. The following project case illustrates the concept:

Project example: Supply chain finance

Initial situation: An electrical engineering company had already made extensive efforts in the past to reduce its working capital. The payment conditions on the customer and supplier side were exhausted. The warehouse logistics and stocks required for production were optimized. It was looking for new ways to further reduce capital tied up.

Objective: Against this background, the aim of the project was to systematically advance the interim financing of liabilities to suppliers and sales financing to customers by involving a third party. By implementing this supply chain finance concept, the company wanted to optimize its working capital by a further step without getting into target conflicts with its suppliers.

Approach: The project was completed in four steps. First, the potential in terms of working capital reduction was estimated in the form of a business case. In the second step, the operating model for supplier and sales-side financing was developed. This included the selection of a financing partner and the specification of the financing conditions. The subsequent implementation of the supply chain finance processes also provided for piloting in different constellations, e.g. with different invoice and delivery addresses and IT integration of the value-added partners. Finally, the supplier- and customer-wide market launch was prepared and implemented.

Result and digital relevance: By introducing the supply chain finance concept, it was possible to shorten the payment term vis-à-vis suppliers by almost 30 percent and reduce receivables from customers by around 25 percent. The project example also showed the potential of networking different value creation partners in the course of a digital supply chain, for example when Supply Chain Finance is used as an intelligent service or via an "App" in individual cases.

Success factors: The success of the project depended crucially on the acceptance of the new Supply Chain Finance offer on the part of suppliers and customers. On the supplier side, it was important to correctly assess the company's market power in the respective product group. On the customer side, the new Supply Chain Finance offer could be positioned as a customer-friendly value-added service, which was conducive to acceptance.

3.3.5 Information logistics

Information logistics comprises the information services of the administration and disposition, i.e. the processes connected with order processing and the tasks serving overall operational control (similar to Augustin 1990). These two areas will be examined separately in the following, before the basic patterns of information logistics will be addressed.

Administrative logistics

The **order processing** characterizes all activities for the passing on and treatment of customer orders, including the internal orders initiated thereby as well as information and communication procedures (Pfohl 1972, the same 1990, Türks 1972). In principle, every order is processed on the basis of information that anticipates the flow of goods (time orders), accompanies it (handling regulations for hazardous goods, consignment notes for hazardous waste, delivery notes) and follows it (control information, invoicing). However, these are shown in a limited **substitutive relationship** to each other. For example, linking order processing makes it easier to implement more anticipatory information flows instead of lagging information flows. It concerns intra-organizational interfaces as well as inter-organizational interfaces and can be achieved, for example, by standardized order forms that are made available to customers. The introduction of electronic data processing systems as well as the establishment of **EDI** interfaces - in particular the iso standard 9735 "Edifact" (Electronic Data Interchange for Administration, Commerce and Transport) - is also a suitable solution to enable remote data transmission (RDT). In the context of new digital supply chain technologies, new standards are also being developed, for example for the use of a cloud to control object flows or based on blockchain to proof origin. Such forms of linking help to avoid manual work as well as duplication of work. The reliability of the information associated with integration then makes it possible to dispense with ex-post controls in particular. On the other hand, the lack of a link results in more lagging information and longer processing times. If one considers in this context that the order **processing time** is a major factor in advance of the delivery time, which can in practice amount to up to 75 percent, the importance of linking administrative processes for the delivery service becomes clear.

Order centers and merchandise management systems

If the order processing processes are bundled not only in terms of IT but also spatially, this is also referred to as **order centres**, i.e. shared service centres for the administrative processes of supply chains. Such spatial integration makes sense above all if the processing processes require a certain amount of manual processing despite IT integration via cloud computing, robots, etc., and if spatial grouping allows a more efficient work organization because, for example, statistical balancing effects can be realized in capacity utilization. The structure of order centers is also superior if the technology used is distributed IT systems that support decentralized work in the form of a **virtual order center**.

Ten Hompel (2014, translated) summarizes the interplay of bundled order processing and decentralized cyberphysical systems as follows: "Above all, there is a cloud-based administration on which the economic goals and strategies are implemented. Here, customer orders are processed in a conventional way, orders are triggered, and finances are managed. But when it comes to real-time, application-specific processing, when things get moving, the multi-agent controls of the cyber-physical systems take over the work - the CPS of the intelligent cists, shelves and vehicles."

Computer-aided **merchandise management systems** (e.g. Zentes 1994) are to be mentioned for the retail sector. The use of these systems in conjunction with customer cards such as the Payback card, for example, provides retailers with significantly greater transparency regarding buyer behavior, because behavior patterns can be traced in a customer-oriented manner. In addition, acatech (2011) emphasizes that intelligent and networked objects are used especially in retail. Increasingly, the "digital product memory of objects" is also being used to optimize processes, especially in supply chain management. The objects adapt to digital business processes as required and communicate. This makes it possible, for example, to track orders via the web.

Multi-channel management, CX and foresighted planning

Multi-channel management is particularly important for administrative logistics, i.e. the use of various communication and sales channels for information and order processing using the Internet or Internet-like structures. Multi-channel management requires real-time information in order to synchronize the various channels. It provides benefits to order processing, but can also offer advantages for advertising, pricing and distribution of products (Heinemann 2012).

Studies show that consumers are increasingly looking for and buying information on the Internet because the possibilities for comparison are better on the Internet than in retail and ordering is easier. Pricing on the basis of suitable algorithms in real time and with the aid of search engines allows suppliers to always make the most cost-effective offer. And the virtual delivery of products, for example software, can replace conventional distribution channels such as the dispatch of software via CD-ROM via an express service provider.

The discussion of multi-channel management is not limited to retailers but also relevant to manufacturing companies that can sell and deliver via various channels. In this context, it is important to mention that the **customer experience** (CX) is not limited to the steps of the ordering process. Customer experience is including everything that creates a point of view for customers and thus includes delivery and service aspects as well as general marketing or recomendations by friends and family networks. Many company limited their CX efforts to the design of the internet website, which does not address the full potential. Typically, supply chain management is heaving a significant influence on the customer journey in this sense and is part of a corresponding experience.

In order to process orders ahead of time, companies can use **predictive planning** to anticipate future orders using statistical forecasting procedures and control their internal processes on the basis of this forecast. Predicting purchasing behavior also makes it possible to proactively approach individual customers if it is assumed that they are likely to buy at a certain point in time, i.e. pick up an order. Foresighted planning makes sense if the statistical quality of the forecast is so high that its costs and the costs of a possible later correction of the forecast, i.e. of the internal order backlog, are more than compensated for by the time advantage of the anticipatory approach. The **quality of the prediction** depends on its statistical validity, reliability and objectivity. For this reason, these companies use customer cards, for example, to monitor individual customer purchasing behavior, purchase customer information from third parties and develop suitable profiles of the behavior pattern. This is because the quality of the data increases when different data sources are combined. In addition to the anticipation of orders, the methods of predictive data analysis can also be applied to individual circumstances of the disposition, for example to the anticipation of traffic jams, order changes, inventory differences, etc.

As mentioned earlier, a core element of information logistics is the S&OP process (Sales & Operations Planning). The use of large amounts of data (big data) and predictive analytics offer possibilities to raise the S&OP process to a higher quality level, which is illustrated in the following case:

Project example: Predictive S&OP

Initial situation: A retail company for clothing and sporting goods was exposed to extremely cyclical fashion trends with only very short product life cycles. Vertically integrated competitors reinforced this trend with increasingly short development cycles of only a few weeks in some cases. The frequent introduction of new collections led to life cycles and shopping cycles in some segments approaching each other almost completely. Overall, this increased the risk of misjudging demand for certain items, leading either to overstocking or to lost sales because the company was unable to meet demand. For 54 percent of the articles, the deviation from actual sales was more than 25 percent. Demand planning thus became a key success factor, with conventional forecasting methods increasingly considered inadequate.

Objective: The aim of the project was to improve forecasting reliability using innovative planning methods. By setting up a forward-looking S&OP process, overstocking and lost sales were to be reduced. The company aimed to achieve a forecast deviation of notlost more than 25 percent in the medium term t with a maximum of 10 percent sales.

Approach: The project was completed in three steps. In the first step, a data cube was set up. Relevant secondary data was collected, as well as additional primary data via newly created consumer panels. The latter exercise was necessary above all because the company used both multivariate statistics and prognosis parameters based on behavioural science when selecting the methods. The forecasting approach distinguished, among other things, between an affective, conatitive and cognitive dimension, whereby the latter could be measured, for example, by Bayesian statistics, which measures the degree of personal conviction. In the second step, the data were examined for exemplary regularities in order to apply any identified statistical correlations to the pattern prediction. Among other things, variously parameterized and explorative factor, cluster, regression, variance and discriminant analyses were used. Randomly selected data samples from the past were used to check the reliability of forecasts and compared with actual sales. An iterative approach ensured the gradual improvement of the forecast results. In the third step, the new planning methodology and the revised planning process were transferred to regular operation. The responsible employees were extensively trained for this and the reporting was revised. The consumer panels that had been set up were maintained on a permanent basis, which was later used for other market research tasks as well.

Result and digital relevance: The short-term increase in planning reliability was accompanied by earnings increases in the double-digit million euro range. The company expected further potential in the medium term as a result of the continuous further development of the methodology.

Success factors: The project had to cope with three success-critical factors in particular. First of all, the proper application of multivariate statistical methods for pattern recognition and prediction was a decisive factor for increasing the forecast quality and implementing the improvements. Secondly, a sufficient data depth and width was required to place the analyses on a sufficient basis. Data integration was accordingly important. And thirdly, the active inclusion of behavioral aspects of consumers in the course of primary data collection was critical to success in order to ensure the necessary customer perspective.

Dispositive logistics

Production planning and detailed steering (PPDS) can be understood as the germ cell of disposition (Kern 1992). Relevant steering instruments aim at supporting the development of a joint disposition for production, procurement and distribution logistics (Diruf 1994). Traditionally, such instruments try to establish plan-directed flows of goods at the beginning of the value-added process as far as possible in the course of a flow-oriented design of operational processes. The

decoupling point defines the step of the value chain that attaches anonymous products to customer orders. In line with the integration concept of supply chains, it can make sense to shift such decoupling point to the end of the value chain if possible.

Against the background of PPDS, the control concepts of logistics can now be arranged according to the type of complexity management. Conventional PPDS systems like the MRP are characterized by a step-by-step processing of planning and control steps. Schedule, capacity, sequence planning etc. are successively run through. However, this linear form of disposition often leads to a denial of process complexity due to its closed system of unlinked subtasks and can thus fall victim to the trivialization trap or **controllability illusion** already mentioned. Newer concepts therefore try to master this problem in a different way, namely by modifying or extending the conventional methodology. But also newer concepts such as MRP II often do face dificulties to manage the complexity properly. While the processing of different planning steps is better integrated, the execution of such planning is still challenged by high market dynamics. For example, rush orders and change requests make the planning partly obsolet during the production freeze. This is why digital supply chains often need a new, demand oriented paradigm that support the complexity of digital supply chains.

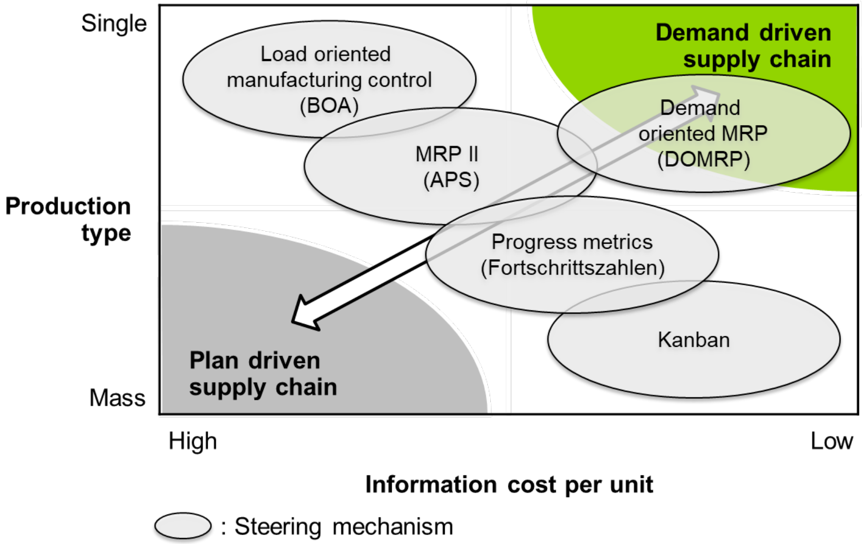
The **production type** answers the question of whether there is workshop and flow production or individual, series and mass production. The type of production is a central complexity driver of production logistics and it is closely related to the more recent control concepts. In the following, we want to classify the most relevant control concepts, accordingly (Figure 3.13):

- The **load-oriented manufacturing control** (BOA) is based on the recognition of the high importance of the average order backlog of production systems as well as of individual workstations in particular for the average throughput time of orders, weighted by order size. The system behaviour, i.e. the representation of the lead time as a function of the stocks, is expressed in so-called "operation curves", which are to be determined system- and operation-specifically. Order intake thus becomes the central variables of the PPDS. The BOA then distinguishes between three parameters, the length of the planning period, the width of the pre-emptive horizon and the height of the load barrier. It represents a form of progressive scheduling, is suitable above all for individual production, but also for the production of small series and is therefore primarily addressed to workshop production (Wiendahl 1987).
- The **MRP II** (Management Resource Planning) presents itself in its core as an extension of conventional PPDS systems by further operational planning sys-

tems, in particular the primary requirement planning. It tries in this way to correspond to the process orientation in the narrower sense (behaviors in the system) and the accompanying integration of the disposition systems of procurement, production and distribution. It is based on the MRP I (Material Requirements Planning), which is dedicated to the scheduling and planning of material requirements. The MRP II finds its employment particularly in the manufacturing of large, in addition, small series.

- The concept of **progress metrics** (so called Fortschrittskennzahlen) is primarily suitable for the production of large series and thus for flow production (e.g. Zibell 1990).
- The **Kanban** concept is also based on the above-mentioned relationships between the average order backlog on the one hand and the lead time on the other. It deviates however in its plant substantially from the conventional PPDS procedures, by structuring the goods flows in form of intermeshed control loops. The pulling principle replaces the pushing principle. If a certain demand exists in a production and value-added stage, it is covered from a buffer store. The replacement order, which is required to maintain the buffer stock, is given to the preliminary stages by an information carrier, the so-called kanban. This triggers a sequence of demand chains, based on the primary requirement, in which the flow of information is opposed to the flow of goods. The Kanban concept is therefore clearly characterized by the JIT philosophy. On the other hand, it takes into account the basic idea of self-organization to a great extent. The Kanban concept finds its application primarily in series and mass production. It offers an appropriate basis for flow production in particular (especially Wildemann 1983).
- And others, for example so-called "chaotic material flow systems" (Wölker/Holzhauer 1995).

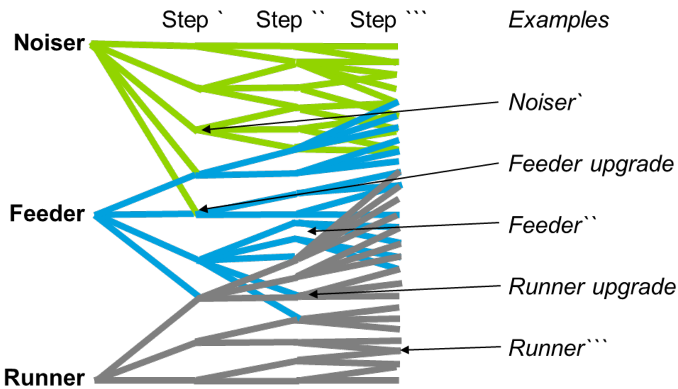
Figure 3.13 Selected methods of process control (based on Warnecke et alias 1994 and complemented by Wehberg 2015)



The classic steering concepts listed above must be rethought and further developed in the light of digital supply chains. In addition, the increasing importance of conserving natural resources places new demands on the management of the value chain and production in particular:

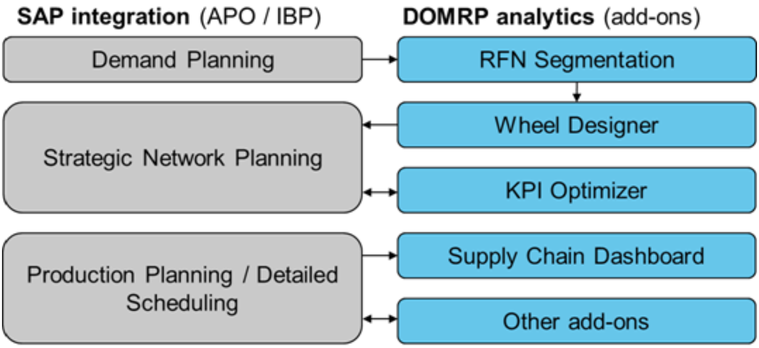
- The **Demand Oriented MRP (DOMRP)** logic, therefore, combines proven push mechanisms with pull principles where relevant. By doing so, it combines S&OP based with lean management capabilities while considering heterogeneous supply chain modles. For DOMRP, it is vital to understand that an end-to-end supply chain needs to make sure that the principles of a digital supply chain and the PPDS in particular are consistent with eachother. Corresponding steering logics and design principles such as self-organization and generalization thus have to be considered on the shop floor and vice versa. Moreover, PPDS algorithms have to be distinguished for each step of production. Often, two different (semi) finished products share the same input material or product of the preceding step, which can lead to so called upgrades Feeders and Noisers (RFN upgrades) as consequence (Figure 3.14). The planning part of DOMRP has to be seen dynamically, so that predictions have to be further developed dynamically with means of meta-algorithms and corresponding alerts. Also, the RFN segmentation is a contininous effort.

Figure 3.14 RFN upgrades within the bill of material



DOMRP has not been comprehensively considered by standard software like SAP, but is expected to be incorporated as part of the innovation pipeline of such vendors. This basically includes the segmentation of supply chain models, the considerartion of proper PPDS mechanisms in terms of an adjusted production wheel, optimzation procedures as well as dash boards amongst others (Figure 3.15).

Figure 3.15 SAP add-ons for Demand Oriented MRP



Ant algorithm

The use of cyberphysical systems in manufacturing can offer the possibility of self-control and the associated **flexibilisation** of large series in the direction of a batch size N =1 (see Figure 3.10 again). The decoupling point of a digital supply chain is ideally shifted further forward in the value chain. Digital supply chains aim at combining the cost structure of large series with the flexibility of small series. The favourable cost structure can be made possible by the lower specific costs of information logistics, i.e. above all the lower disposition and IT costs per service unit. Bauernhansl (2014, translated) states: "The ramp-up as a set-up process for the entire factory is becoming an everyday occurrence.“ And he continues: "We still work according to the Taylorist principle of division of labour: belt and tact are the core, the pulse beat of the pyramid of value creation. This will no longer work in the future. Since we also define the production quantity and flexibility with the definition of the cycle and limit the number of variants and variant flexibility with the linking of the value-added steps," he adds. This does not necessarily mean, however, that a standard tact is not applicable anymore when determining production wheels especially in a cross-asset and cross-site mode.

Depending on the industry sector, product features and production technology, high set-up costs can stand in the way of making production more flexible, so that the **cost efficiency of digital supply chains** must always be assessed on a case-by-case basis. In addition to cost efficiency, improved delivery flexibility and customer orientation can speak volumes for the use of a digital supply chain (similar to acatech 2015).

The self-control of the smallest production units, i.e. parts, semi finished products and final products, requires a high degree of decentralised control intelligence, for which the use of cyberphysical systems is a necessary prerequisite. In addition, the control algorithm itself must be seen as a sufficient necessity. In this context, the example of the **ant algorithm** in relation to digital supply chains is often cited to underline the crucial importance of the correct mathematical representation of the behavior of highly complex systems (Bousonville 2009). In the search for food, individual ants excrete pheromone along their path. Other ants are more likely to choose a path with a higher pheromone concentration. This approach of ants can be described as swarm intelligence: a higher performance (here the search for the shortest route) is achieved by the interaction of many simple actors who can only contribute a part to the overall solution. The interaction of the smallest production units in the course of a digital supply chain will have to function comparably (Hirsch-Kreinsen/Weyer 2014).

The following project case by Schlick et al. (2014) emphasizes the importance of system integration for self-control in manufacturing using the example of paper-based operational and IT-based medium-term production planning. The focus is on the synchronization of both planning processes:

Project example: Escalation management

Initial situation: A medium-sized company used a production planning and detailed scheduling system (PPDS) to plan production orders. This supported the IT-related mapping of the timing of orders in the course of the overall planning. At the level of individual production steps the company worked with planning boards which, according to the principles of lean production, made it possible to organize production on the basis of a paper-based card system. The approach was therefore characterized by a media discontinuity between the IT-supported medium-term planning horizon and the paper-supported operative planning horizon. Both planning horizons were manually adjusted with a lot of effort.

Against this background, the management of escalations was also hampered by media disruptions. "Media disruptions occur because information about the reason why an order cannot currently be produced is insufficiently documented. (...) This also results in a longer machine downtime. In addition, the media break prevents statistical evaluation and thus a return of knowledge regarding the causes of the problem." (Schlick et al. 2015)

Objective: In order to avoid such media disruptions, to increase transparency and to be able to make decisions quickly, the company aimed to ensure that the relevant order, machine and line-related data are available and processed appropriately at all times. "In order to be able to react quickly and accurately in the event of an escalation of problems during order processing, people must be put in the centre of attention when creating an escalation, entering information and retrieving information (Schlick et al. 2015).

Approach: The company chose a three-step approach. In the first step, the planning board was digitized to eliminate the media disruption. Employees at the planning level were given the opportunity to access the current status of the digital planning board system via various terminal devices. The visualization of the production orders was structured in tabular form, for example sorted according to individual production lines and using color codes. Depending on the role of the user, different views could be set, e.g. daily planning, machine occupancy, planning for a specific line, etc. The user was able to select the most suitable viewpoint for the job. The second step involved the development of a program function that would enable the production employee to directly document the processing of orders and, if necessary, to identify problems. "Order and (..., machine data can...) be entered by scanning optical markers on order papers or on processing machines. In a third, longer-term step, the information collected on delays in order processing and their causes is transferred to a continuous improvement process." (Schlick et al. 2014)

Result and digital relevance: The benefits of system integration lay primarily in the improvement of the organizational process for order processing and could therefore only be quantified to a limited extent. In the short term, the simpler escalation of problems in the production process was the top priority. The digitization of the escalation process during order processing makes it possible to use statistical methods to recognize patterns in the behavior of machines and equipment. In the medium term, this will enable decision-makers to eliminate specific causes of escalation and continuously improve the planning process. The corresponding pattern recognition, as a core component of a digital supply chain, then shows results.

Success factors: A decisive factor for the successful implementation of such a project is typically the willingness of the managing and operative employees of the company to invest in the IT processes of production, even though a large part of the benefit can only be gained in the medium term through corresponding learning gains on the basis of statistical evaluations. Furthermore, sufficient transparency and knowledge of the planning processes in production are critical for success, which in turn requires the close involvement of those involved in planning.

Green manufacturing

Due to the increasing importance of conserving natural resources, production control concepts will in future have to take greater account of **energy cost efficiency** in the form of "green manufacturing". The energy cost efficiency of a company basically comprises two areas of improvement, namely improvements on the supply and demand side. The latter are also referred to as demand management. Supply-side measures include, for example, the purchase of electricity, gas, heat and compressed air, the in-house generation of secondary energy and building energy efficiency in the form of energy-saving lamps. Energy purchasing in sectors such as the automotive industry is generally already largely optimised. Since the majority of the energy required by a company is consumed in production, demand-side measures in production in terms of green manufacturing, offer a major improvement lever.

Of course, energy-saving measures in production are not new. Most companies regularly check where energy consumption can be reduced in production through technical measures such as the use of heat exchangers amongst others. Green manufacturing also aims to systematically smooth out any deviations in the load curve, which means it tries to flatten the energy consumption curve. Strong fluctuations in the load curve are typically expensive for the energy supplier because peak demand generally determines capacity requirements This is why very constant demand is typically much cheaper for the company. The core of green manufacturing is therefore the fusion of classic steering concepts of production planning and scheduling with load management in the energy sector. In addition to load management, other parameters such as capacity, batch size, sequence, adherence to schedules, etc. must also be taken into account. Suitable work organization measures, such as raising the machines at the beginning of a shift, are used to smooth the load profile and, in particular, avoid peak loads.

In individual cases, the use of **energy storage** devices can support this, even though storage technology is still comparatively cost-intensive. In this context, the integration of the company's vehicle fleet offers a promising approach by absorbing or buffering excess capacities of the company's own generation of electricity and peak demand via the storage facilities of the electric vehicles. In addition, the performance of the batteries of electric vehicles decreases significantly in the course of their operation, so that batteries can also be used as energy storage devices after they have been used in the vehicle.

In order to be able to connect the classic PPDS key figures with the load curve management, a differentiated measuring system is required to record the energy consumption. The demands on measurement technology increase even more when service providers of energy supply and efficiency have to be invoiced according to performance. The **smart meters** and electricity grids used here are based on the same technology of cyberphysical systems as digital supply chains itself. Green manufacturing is also the subject of digital supply chain management in this respect.

Intelligent energy supply and digital supply chains have many points of contact, especially in energy-intensive companies like Process Industries. Against this background, the following project case shows how environmental protection and cost efficiency can be harmonized:

Project example: Energy cost efficiency

Initial situation: In the past, a company in the manufacturing sector had identified numerous measures to save energy costs. However, a large part of these measures was not implemented because the economic efficiency did not meet the company's standards. The majority of the measures implemented were also on the supply side (e.g. structured purchasing of energy) and not in production. The latter was the main source of demand in the company.

Objective: In order to identify possible further savings in energy costs, the company set up a review. In addition to cost improvements, it was also the aim to use any marketing and image effects wherever possible.

Approach: The project team formed four workstreams, which were to identify and address improvement potentials in three steps. A first workstream focused on increasing own generation of energy, including renewable energies such as PV and wind. A second workstream examined existing measures that had not yet been implemented due to their economic viability. Most of these measures were in the area of building energy efficiency. A third workstream dealt with the production area, i.e. a corresponding stabilisation of the energy demand there. A fourth workstream examined fleet management. In the first step, the status was recorded, which means the energy consumption and corresponding drivers were documented. In the second step, starting points for improvement were collected and prioritized. And in the third step, the prioritized measures were handed over to those responsible and the planned savings effects coordinated with the controlling department.

Result and digital relevance: More than 15 percent of energy costs could be saved, although the company had already made extensive efforts in the past. The production area in particular offered significant cost savings potential. For example, the project team found that around 20 percent of the load was caused by 31 hours of demand alone. On the other hand, no electricity was consumed at all in 755 hours per year. The use of renewable energy enabled the company to present itself positively in terms of environmental protection. And by integrating suitable energy service providers, it was finally possible to reorganize numerous business cases or measures, even though these did not meet the company's economic efficiency standards. The service providers could be strongly tied to success and their contribution to success was tracked by intelligent measurement technology.

Success factors: The success in this project is mainly due to three factors. On the one hand, the review of innovative savings ideas and the expansion of the scope of the study were critical to success. In the past, improvement levers such as load curve management in production were simply not considered. Secondly, knowledge of the service market was crucial. This market is currently very much in motion and new suppliers are partly prepared to implement and finance measures despite moderate profitability. Such providers are exposed to other expectations on the part of the capital market or also have very lean medium-sized cost structures. Last but not least, the company's openness to see energy efficiency not only as a cost issue, but also as a strategic marketing issue was very important.

Predictive maintenance

A not insignificant portion of production costs is caused by maintenance and repair processes. Predictive maintenance aims to make the corresponding activities for logistics and production capacities (but also for customer plants in the course of customer service) more efficient by controlling them according to demand through the use of networked sensors. The aim is to use the measurement of relevant data to identify **patterns in the machine park** that anticipate a probable machine breakdown and the corresponding maintenance requirements. Maintenance activities as well as shut-downs of production can be organized more efficiently, and available capacities in terms of the operational equipment effectiveness of production assets can be planed more reliably. Such predictive maintenance can be relevant both in the company's own production and supply chain operations as well as in customer service, which means in the customer's machine park. Many companies, on the other hand, plan their maintenance according to certain empirical values in time intervals or production quantities in order to anticipate failures based on their condition – so called **time-based maintenance** - or only react in the event of failures.

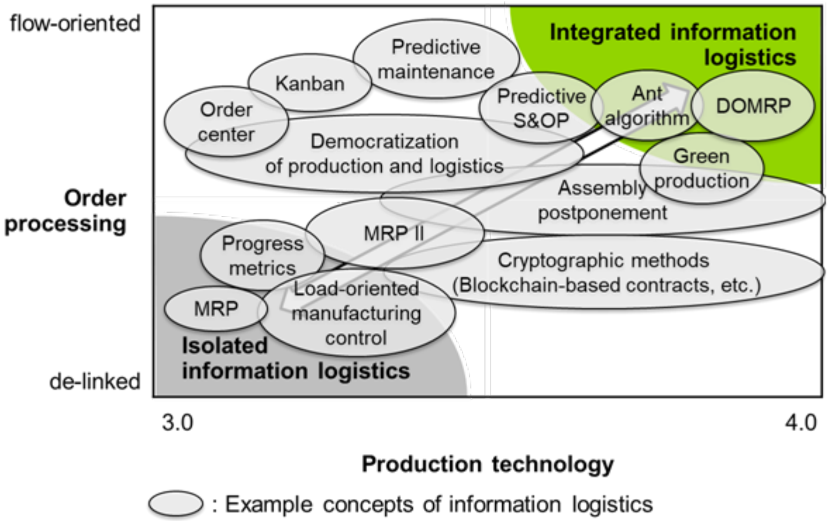
Vogel-Heuser (2014) points out that, within the framework of the fourth industrial revolution, production units have the ability to monitor themselves and, if necessary, to counteract themselves appropriately. Schlick et al. (2014) see in this context four successive **stages of the intelligent behaviour** of production systems which correspond to the characteristics of digital supply chains (recursion, autonomy, redundancy and self-reference) mentioned already in Part 2 of this publication:

- Communication and distributed functionality (network of mechatronic systems),
- Adaptivity and autonomy (independent set-up and autonomous processing),
- Context-sensitive, cognitive machine systems (dynamic environmental adaptation),
- Self-optimized systems (independent target definition for holistic optimization).

Integrated information logistics

In summary, two typical extreme forms can be identified for information logistics (Figure 3.16). On the one hand, there is **isolated information logistics**. The lack of linking of administrative processes leads here to an increased realisation of lagging order information. High throughput times of order processing justify a correspondingly stagnant flow of physical execution actions. The weakly pronounced change in information logistics is expressed in particular by the industry 3.0 kind of production, e.g. in terms of traditional workshop production in the course of PPDS. On the other hand, there is the **integrated information logistics**, in which the networking of administrative processes allows a flow-oriented structure of the flows of goods, but also presupposes this in reverse. The supply chain structures in line with the organizational concept of flow production and industry-4.0 technology. The change associated with them is correspondingly high. Due to its high system complexity, information logistics designed in this way is able to handle a large number of different processes while taking into account the principles of green manufacturing.

Abbildung 3.16 Change profile of information logistics



The area functions described so far basically characterise both the supply and the disposal side of supply chain processes in more or less equal measure. In addition to the collection and separation function of waste disposal logistics, which is not attached to the supply logistics, it is also characterized by other special features, so that the following separate consideration appears appropriate.

3.3.6 Logistics for the circular economy

Recycling

Disposal logistics characterise the "application of the logistics concept to residual materials" (Pfohl/Stölzle 1992, translated). Against the background of the theory of joint production (Riebel 1955, Bührens 1978), residual materials can be characterised as an output of operational processes in the broadest sense (production, logistics, administration, consumption, etc.) which has no direct relation to the objectives of the company and logistics in particular (Stölzle 1993). A distinction must be made between reusable and non-reusable residual materials. Re-usable residues are suitable for recycling, which means for recovery or use. They are also referred to as **recyclables** or "wastes for recovery" (e.g., as per § 3 para. 1 KrW-

/AbfG in Germany). In contrast to residual materials that cannot be reused, so-called **residues** or "waste for disposal", which are disposed of in an orderly manner, they generally imply a technological feasibility and economic advantage of reuse. However, the transition between recyclable and non-recyclable residual materials is fluid, because with the increasing number of reuses due to the so-called "**downcycling**", which means the diminishing quality of the residual material, the recyclability is reduced (Rautenstrauch 1993). And even the assessment of the technological representability and economic efficiency of recycling is probably not without a subjective moment. And so can be the differentiation between waste and distribution logistics, accordingly. Needless to say, the most efficient waste logistics is those never needed unless the **avoidence** of waste is not overcompensated by other harmful effects.

Synergy management

A special feature of waste logistics now arises from the fact that the flow direction of its processes is opposite to that of supply logistics, at least in the case of recycling and reuse. This offers corresponding connection potentials, so-called synergies, which extend beyond the field of waste logistics and refer to the connection of supply and waste logistics processes. The latter potentials can be described as external, the former as internal synergies. The design of **internal synergy** potentials in waste logistics has hardly any special features compared to the supply logistics (in-depth Wehberg 1997). Its exploitation can therefore be traced back to the intra-process coordination task of supply chain management. In contrast, the use of external synergy potentials and thus interprocess coordination are more demanding (for the concept of 'synergy' and its roots see Göpfert/Wehberg 1996).

External synergy potentials of waste logistics can be found in the form of **factor synergies** and **process synergies** as well as **result synergies**. Furthermore, it seems helpful to differentiate the synergies according to whether they are characterised by a high or short service life, large or small influenceability and to what extent the synergy effects occur directly or indirectly in terms of time.

Although the three forms of synergy must not be seen separately from each other, as they partly build on each other in the form of medium-purpose-relationships, their separate consideration seems to be helpful at first. So how are the contents of the individual forms of synergy presented in concrete terms? With regard to factor synergies, which result from the linking of the input factors of the service production process, the differentiation according to repeating and potential factors (Gutenberg 1983, translated) can be made, which can be specified both in their quantitative and qualitative dimension. Repeat factor-induced synergies seem to be of less importance here, insofar as waste logistics is aimed precisely at minimising the use of consumption factors through the implementation of the closed-loop concept or recycling. In the majority of cases, the avoidance of the use of repeating factors is bought at the expense of an increased use of potential factors, as can be seen from the example of returnable transport packaging. With regard to factor synergies, concentration on potential factors therefore seems appropriate. **Potential factor-induced synergies** are also generally characterised by a relatively long service life and great influence. The larger the range of services (Wehberg 1994) covered by the potential factors in the area of supply and waste logistics (qualitative dimension) and the smaller the sum of the capacity requirements of the two areas together (quantitative dimension), the higher they are. By way of example, any capacity overhangs can be reduced by adding waste logistics services and the management know-how can also be made fruitful in the field of waste logistics. Göpfert and Wehberg (1996) provide a more in-depth description of the potentials and influencing factors of external factor synergies.

External process synergies are the result of linking the actual supply and waste logistics processes. The excesses of possible process energies are as complex as the manifestations of processes themselves. A systematization according to **X- and Y-synergies** thus facilitates the perception and design of such sources of advantage (based on Porter/Fuller 1989): X-synergies are the result of the interaction of different processes that complement each other, i.e. interlock with each other to a certain extent. Their starting point is the asymmetric course of supply chain processes. Paired transports between de- and supply logistics can be cited as an example. With regard to the latter, however, the complete takeover of existing route plans will not always be possible if, for example, connections blocked for goods subject to declaration may no longer be used. If several customers are to be reached over the same area, it should also be noted from a transhipment perspective that shipments to be unloaded and loaded do not stand in each other's way. The latter is likely to be the case with pure hedge loading. Rear-side unloading and right-side loading is a practical alternative here, which, however, requires appropriate fleet equipment. In addition, if the goods to be removed are only dismantled and expanded in the course of time-consuming multi-man handling, the external synergy advantage of the transport pair can be overcompensated by the time disadvantage caused by this.

Y-synergies, on the other hand, are due to the linking of similar processes and are based on symmetrical process structures. Examples of this are the bundling of transports.

Pattern visuals

Irrespective of whether these are X- or Y-synergies, the recognition of such process synergies as well as factor synergies is in reality associated with great difficulties. These are highly complex facts. The erudition of such synergies thus becomes the task of pattern recognition. Due to the possible complexity of process relationships, the detailed analytical approach often offers only little assistance. The **recognition of synergy patterns** presents itself as a synthetic process that requires a great deal of creativity, but also the trust of management (Sprüngli 1981). It is based on the already mentioned methods of predictive data analysis. It has proved helpful to present muster in visual form. The human eye is the organ whose synthetic abilities are probably the most trained and developed. As a rule, vision takes place holistically. For the recognition of external synergy patterns, as of certain process patterns of the enterprise in general, the use of so-called pattern visuals seems to be particularly suitable. The visualization of process structures offers the management the possibility to uncover legal relationships. For the purpose of graphic representation, the relationship patterns are brought into two- and also, in particular with online graphics, three-dimensional representations. Possible description dimensions – not limited to identifying process synergies - are:

- Spatial dimensions (source, sink, transshipment points, direction, etc.),
- Time dimensions (hour, minutes, etc.),
- Supply chain objects (residual materials, intermediate products, end products),
- Supply chain subjects (cooperation partners, logistics service providers, etc.),
- Supply chain performance indicators (delivery time, transport cost, planning accuracy, etc.) as well as
- Indicators for the description of the operational supply chain processes themselves (transshipment, transport, storage processes, etc.).

Corresponding **ways of visualization** include the following methods as examples:

- Tag clouds visualize text as weighted list
- Clustergrams show assignments to clusters
- History flow charts document the evolution
- Spatial information flows show geographical links

- Ramler plots show grafic pattern overviews

In addition to factor and process synergies, there are also result synergies. They result from the overall view of the results of two or more supply chain processes and can be differentiated according to cost- and performance-oriented synergy effects. In particular, the cost advantages can be seen as a sequence of the factor and process synergies just explained. For example, they go hand in hand with an even utilization of logistical capacities. Performance synergies, i.e. earnings synergies located on the performance side, comprise both any higher strategic robustness and an improvement in the operational delivery service such as flexibility. Increases in robustness may be due to the fact that, despite a sudden increase in the volume of waste logistics, the company can dispense with capacity expansion due to external synergies and is therefore in a position to cover the capacity requirements that now exist from the supply logistics facilities. The external synergy potential here forms the basis for a flexible deployment potential (Wehberg 1994) for waste logistics. Some companies are also faced with the favourable situation of being able to offer waste logistics services to other companies. The high level of competence that has been built up in the field of waste logistics can then be marketed and, if necessary, allows the core business to establish another attractive business area. Such a diversification from a pure product manufacturer into the service sector also has the effects of increased robustness.

Irrespective of which form of recycling is chosen and whether it concerns internal and external waste logistics or the disposal of production residues, end products, transport and product packaging, the potential of factor, process and result synergies now also and especially depends on the **organisation of the reusable system**. As an example, an:

- Individual,
- Bilateral and
- Pool system

can be distinguished for the reuse of transport packaging (Lange 1994). Decisive factors here are primarily the degree of standardisation of multi-way packaging and transport control in the area of waste logistics. Thus "individual systems" are characterised by company-specific packaging and transport flow solutions. In this way, they take the operational requirements into account to a high degree and create favourable conditions for the realisation of external synergies. "Bilateral reusable systems", on the other hand, are characterized by standardized reusable packaging on the one hand and company-specific logistics chains on the other. As

standards, they regularly fall back on corresponding standards, such as DIN and VDI standards, which are often industry-specific. As a rule in the course of a 1:1 exchange, a change of transport packaging between different logistics systems is possible due to standardization. In principle, this makes it possible to maintain a lower total stock of packaging as a whole, since short-term peaks in demand among the shareholders of this reusable system can be balanced out. The internal factor synergies here are comparatively high. Due to the individual transport control and execution, the disposal logistics processes can also be linked to supply logistics processes according to the situation, which can result in high external process synergies.

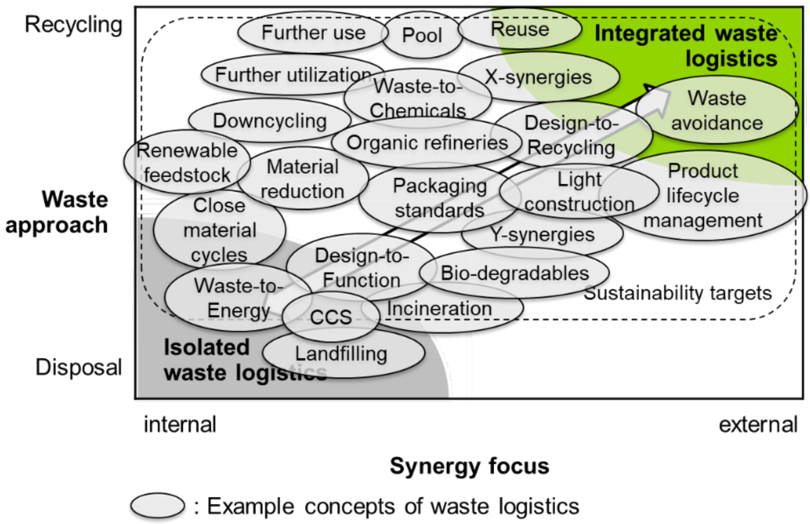
Finally, so-called "pool systems" are characterised by the fact that both the load carriers and the logistics chain, i.e. primarily the transport execution and control, are standardised and shared. The design of reusable packaging, as well as the residual material flows themselves, can be traced back to a common denominator, which is usually embodied in the form of a neutral **pool carrier**. The tasks of such a pool company are then to offer various logistical services and to acquire new members for its returnable solution, i.e. above all to maintain the openness of the pool system. Their aim is to ensure sufficient availability of packaging and rapid disposal, which does not have to be the case in the course of bilateral systems. Advantages of the pool system compared to bilateral and individual returnable systems are also possible bundling effects of return transports in the form of internal synergies. As in the case of the bilateral system, the total stock of reusable packaging can be.

Integrated waste logistics

The overall view of waste logistics design options makes it clear that their change can be profiled above all in the form of the following two extremes (Figure 3.17): On the one hand, there is **isolated waste logistics**, which concentrate on the disposal, i.e. landfilling and incineration, of residues. The starting points for exploiting synergies are limited to intra-process coordination. Any synergetic external relations remain unused. The structures of isolated waste logistics systems are correspondingly stability-oriented. On the other hand, **integrated waste logistics** benefits greatly from the linking of its own processes with those of supply logistics. The high proportion of recycled residual materials corresponds to the development and exploitation of external synergies. In particular, reuse and recycling, which means the reuse of residual materials within their previous area of application, promotes such a synergy focus. Moreover, the avoidance of waste is being considered systematically. It becomes clear that integrated systems of waste disposal logistics imply a comparatively high change. In order to enable that change, integrated waste logistics make use of pattern recognition and self-control processes through the use of cyberphysical systems, comprehensively.

After the exemplary basic and area strategies of logistics management have been explained, the planning profile that reflects the relationships between logistics and marketing will be examined in the following.

Figure 3.17 Change profile of waste logistics



4 Relevance of the digital twin of a product

4.1 Marketing logistics

The coordination of the areas of responsibility supply chain management and marketing leads to the conception of a "**marketing logistics**". The exact concept of marketing logistics is by no means uniformly discussed in the literature, which is why the most common understandings should be grouped as follows: Initially, numerous contributions to marketing logistics equate these with distribution logistics tasks, whereby marketing goals are given special consideration in the course of coordinating the flow of finished products (Pfohl 1972, Traumann 1976). Such an understanding of terms is based on the recognition that the sales area in buyer market situations is usually the bottleneck area of the company (Delfmann 1990 b). If, however, procurement and sales are understood as "mirror-image transaction systems" (Meffert 1986, translated), then in principle both sides need a so-called "Balanced Marketing" (Nieschlag/Dichtl/Hörschgen 1991) of a corresponding coordination. Thus, procurement markets can also advance to become the central operational bottleneck, for example as a result of higher raw material prices (Bowersox/Closs/Helferich 1986). In addition to distribution, marketing logistics also refers to procurement (e.g. Krulis-Randa 1977, Poth 1973). It should be noted critically that the coordination of marketing logistics is not limited to the area of procurement and distribution, though. Rather, production and waste logistics also take on a variety of references to the market (lhde 1978).

Now, marketing tasks can be structured by the 4 Ps, namely product, price, place and promotion. Let`s start with the placing and promotion part of it:

In the course of digitalization it is expected that there will be a renaissance of marketing logistics. Modern customer relationships platforms such as Salesforce bring marketing and sales organizations to the next level. **Placing** will be virtual and thus omnipresent via the internet. **Promotion** develops from advertising to real-life experiences, which are shared in blogs by users. The discussion of the so called customer journey becomes vital for marketing efforts to improve customer loyalty and value added. The more mature such concepts are the more they tend to define the customer journey more comprehensive and not limited to the sales process in the narrow sense. Delivering products at certain service levels and providing spare parts are also part of the journey in the way that they contribute significantly to the experience and thus satisfaction of a customer.

From a supply chain point of view, **product development** offers many chances to simplify logistics, e.g. through modular sourcing and standardization of packages. At the same time, the trend of individualizing products in terms of mass customization is challenging the supply chain organization in many companies. In this context it is key to align both the digital twin of the supply chain and the digital twin of product development, production and the internet of things, which means the appliances on a users`level.

Let`s talk about **pricing**: An important connection between marketing and logistics is the influence of logistics costs on pricing. Many companies do not adequately handle the complexity of logistics-relevant cost drivers, as the following case will illustrate. A so called supply chain management-based pricing becomes vital:

Project example: Supply chain management-based pricing

Initial situation: A company in the process industry found itself under increasing margin pressure due to the increasing commoditization of its products. The analysis of the cost structure showed that margins of numerous products and customers were insufficient and in some cases even negative. In the past, this was not transparent because costs in the logistics and service area were not allocated according to the cause. Instead of taking the specific cost drivers into account, the corresponding costs were distributed equally across all products and customers, i.e. averaged. This averaging resulted in the increased use of corresponding logistics and services in the sales department, without paying attention to cost-effectiveness. From the point of view of the individual sales employee, these services were, so to speak, free goods for which virtually no price was charged. As a result, the use of these services for the purpose of customer loyalty was exhausted to the point of a negative marginal benefit. There was a lack both of sufficient transparency about the actual profit contribution of individual customers and products as well as of a corresponding controllability in the sense of corporate objectives.

Objective: Against this background, the company launched an initiative to improve the margin structure. The aim was to ensure transparency about the "real margins" by allocating costs according to their origin, to put sales pricing on a new footing and to raise profitability in all product and customer segments to a minimum level. The new pricing system to be developed should above all sharpen the focus on the relevant cost drivers, because in B2B business the justification of price increases on the basis of cost driver developments enjoys a high level of acceptance. In the future, the potential of value-based pricing should also be exploited to a greater extent by investigating the willingness of individual customers to pay more, beyond a full cost-based approach.

Approach: The initiative was divided into five steps. In the first step, the current situation was made transparent, i.e. above all an overview was created of key logistics and services as well as the associated quantity and resource structures. The second step developed an appropriate allocation logic for the further development of cost type, unit and carrier accounting, so that the aforementioned services could be attributed to products and customers. Individual calculation examples with surprisingly poor margins acted as "eye-openers" and created the necessary momentum. The adjusted cost accounting system was initially set up in a side calculation parallel to the current SAP cost accounting. On this basis, the sales pricing system was further developed in the third step. In this context, the price potentials per product and customer were determined in order to achieve an acceptable margin level for the company throughout. The customers' willingness to pay was taken into account on the basis of the sales department's assessment and validated in individual cases through discussions with customers. The fourth step involved piloting the new pricing strategy for selected products and customers, i.e. raising prices for products and customers or reducing additional services. The focus of this step was the task of proving the feasibility of the new pricing. The fifth step was to transfer the new pricing system to the line. Cost accounting was also permanently adapted in the SAP system. A new pricing regime (pricing tool) was introduced to support the calculation tasks of the sales department. Ongoing optimization based on a continuously improved understanding of willingness-to-pay and performance expectations was initiated and anchored in the organization.

Result and digital relevance: The company's margins were improved by an average of 1.8 percentage points and the overall result increased by a double-digit percentage. The transparency of costs and cost drivers in the supply chain area also offered significant improvements for the competitiveness of the company, because services could be offered flexibly and individually to customers and the network capability of the corporate logistics could be increased. Especially when supply and demand are coordinated decentrally, a system-based calculation of costs based on cost drivers is a prerequisite for a distributed negotiation process between self-organizing units.

Success factors: Three factors were decisive for the success of the initiative: Firstly, the technically correct mapping of costs and services in the SAP system. Secondly, the willingness of the sales department to participate. And thirdly, the successful piloting of the pricing strategy with initial financial success at an early project stage.

4.2 Service competition and pioneer marketing

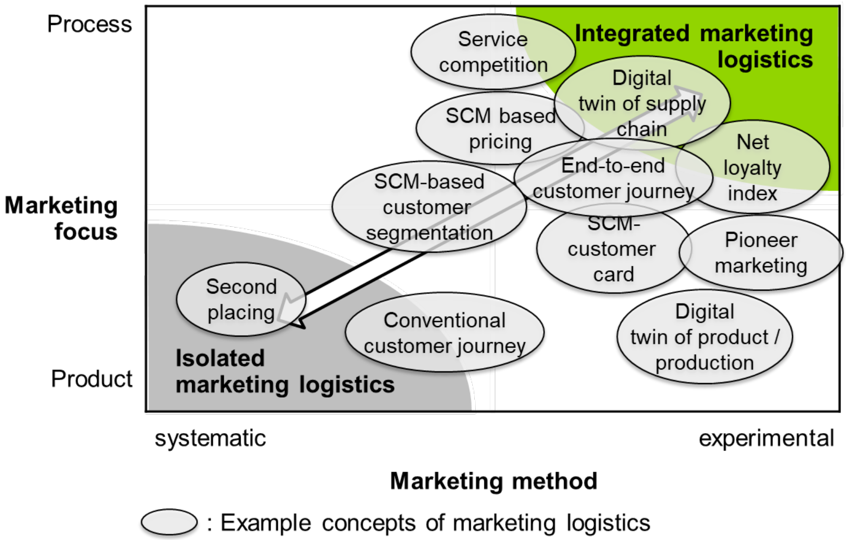
Marketing tasks can concentrate on the one hand on the material product and on the other hand on secondary services such as logistics. In this context, the development from a primary to a secondary competition triggered by the increasing homogeneity of product offerings leads to a shift in the marketing focus from the product to the logistics process. In a similar way, this kond of shift is being triggered by the upcoming stronger **service competition**. For example, Automotive OEMs are not building cars anymore but selling mobility. And Speciality Chemicals companies are not selling chemistry like additives or catalysts anymore but performance. In extreme cases, marketing is limited almost exclusively to logistics or service content.

It is also conceivable, however, that due to the overall pronounced product focus of the branding activities, these and the tasks of marketing logistics will remain completely uncoordinated. With regard to the methodology of marketing, an experimental-creative working method can be distinguished from a systematic, almost technocratic one (Meffert 1988). Marketing tasks in rather static markets are often tried to standardize by introducing administrative procedures. The decisions have to be backed up by appropriate analyses. Such a method of working usually aims to maintain the stability of the range of services and the earnings situation. It can be aptly described as "desk marketing". The experimental-creative working method is different. Especially in dynamic market fields such a methodology can be seen, which, pointedly said, can also be called "**pioneer marketing**", suitable to provide the necessary degrees of freedom in the context of marketing analysis and planning. Among other things, creativity techniques, explorative market research and correspondingly innovative segmentation approaches represent this second way of working. It includes methods of pattern recognition based on the explorative methods of predictive data analysis when it comes to understanding market-relevant behavior patterns within the supply chain. And it makes potential use of the technologies of cyberphysical systems when it comes to implementing innovative segmentation approaches with the necessary flexibility and decentralization.

Finally, the change profile of marketing logistics can be presented in its two extreme forms, isolated and integrated marketing logistics (Figure 4.1). **Isolated mar-**

keting logistics attempts to support product marketing by means of a systematic approach. The traditional marketing of benefits in kind corresponds here with a sophisticated set of marketing instruments and a correspondingly established methodology, which probably also affect logistics in the form of stability-oriented structures. The scope for behaviour in marketing logistics is relatively small here. On the other hand, **integrated marketing logistics** is characterised by an experimental approach and instruments that promote creativity in order to offer appropriate assistance in focusing marketing on logistics services. In logistics in particular, marketing instruments as a whole are still underdeveloped. For example, with regard to the transition from logistics segmentation to market segmentation, the theoretical foundation of a "logistics-oriented market segmentation" (Pfohl 1977 b, Schary 1985) is required. This demand on logistics becomes even more stringent when one considers the increasing tendency towards segmentation and niche formation in the course of digital operating and business models (Anderson 2007). The way of working in this area is correspondingly malleable and immature. The solutions to be implemented in logistics tend to be more differentiated and require a high degree of agility. The spectrum of methods and instruments used is therefore broader and explorative. Not least for this reason, integrated marketing logistics represents change-oriented behaviour patterns in the sense of resilience and digitalization. In practice, marketing logistics has so far often been implemented in isolated form (Duerler 1990). Because in many companies the process of a market-oriented formation of the supply chain system is only in the initial phase.

Figure 4.1 Change profile of marketing logistics



In the sense of integrated marketing logistics, the following application case shows how process and customer perspectives can be effectively linked:

Project example: Logistics loyalty card

Initial situation: A plant engineering company was active in the project, service and product business. The company found that a stronger link between customer and supply chain perspective offers potential for improvement, because many important customers received a rather average delivery service, whereas C customers were partly supplied with high priority. Overall, the delivery service focused more on how well the respective key account manager was able to channel his orders through the internal organization. There was no systematic prioritization according to the strategic importance of the individual customer.

Objective: Against this background, the company's goal was to offer a kind of "loyalty card" for A customers with a view to the delivery service. The company wanted to systematically differentiate the delivery service according to the strategic importance of its customers in order to position itself even more strongly in the market, especially in the project business. The delivery service and logistics were thus to become an important instrument of the company's strategic market development. The rather random dependence of the delivery service on the individual skills of individual key account managers should also be overcome.

Approach: The loyalty card for logistics was implemented in five steps. In the first step, the necessary transparency was created. Since customer contact in the project business was made via project development companies, a way had to be found to first know the customers of the various orders in order to prioritise the orders according to the importance of customers. For this purpose, an incentive system was designed for the project developers to pass on corresponding customer data. In the second step, additional logistics services were defined that were suitable for contributing to customer loyalty. On the basis of customer surveys, these services were determined from the customer's point of view in order to avoid the error of the company offering services from its own point of view that might not offer added value for customers. Examples for corresponding additional services were the activity of customs clearance and a shortened delivery time. Based on the defined catalogue of additional services, these were budgeted by the company in the third step and sub-budgeted to the various businesses (service, product, project). This was intended to counter the danger that the promised additional services might get out of hand and jeopardize the profitability of the company as a whole. In the fourth step, the customer segments to be prioritized were defined on the basis of objective criteria. This prevented individual key account managers from arbitrarily awarding additional services and undermining the customer loyalty strategy at the operational level due to opportunistic sales interests. Service-oriented B customers were also offered a higher level of service at an extra charge, so that the segments were permeable. The key account managers were trained in the new customer segmentation. In the fifth and final step, the connection to the established ERP system was ensured, so that the customer card for logistics could be integrated into the operative billing and ordering processes.

Result and digital relevance: The logistics loyalty card was able to make a significant contribution to customer satisfaction and positioning of the company, especially in the project business. Growth in the project business was almost doubled. Logistics was systematically instrumentalized for the implementation of the market development strategy. Transparency in the project business was also significantly increased, which was beneficial for more extensive marketing strategies. The definition of guard rails and technical system mapping ensured that the loyalty card was not introduced at the expense of the entrepreneurship of the individual key account manager. Rather, the customer card created clarity about the scope for awarding costly additional services and supported self-organisation in the formulation of offers by sales.

Success factors: The decisive factor for the successful introduction of the logistics loyalty card was above all the integration of sales. After initial resistance, the sales staff quickly realized that such a binding and transparent performance promise could set new impulses in market development and raise cooperation with project developers to a new level.

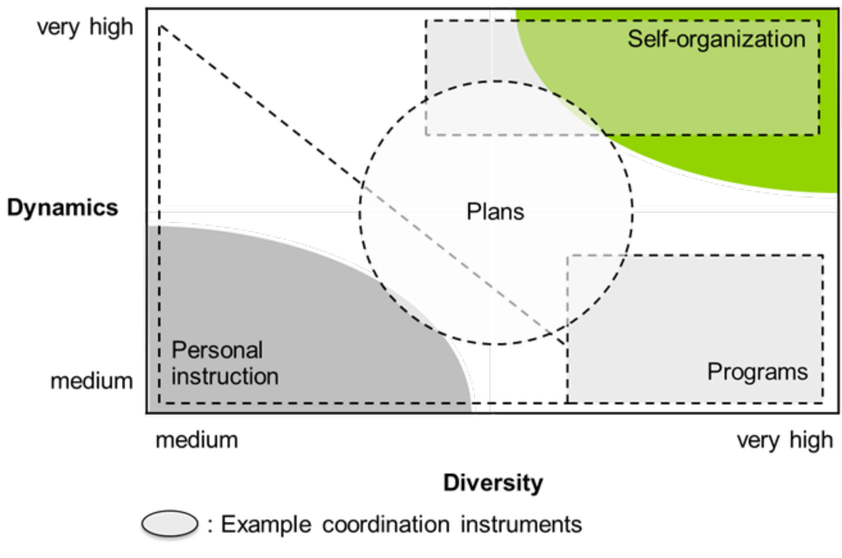
In addition to an effective system building of marketing logistics and the supply chain structures in general, its resilience largely depends on the quality of the day-to-day coordination in terms of system coupling.

5 Coordination along the chain

5.1 Supply chain coupling

We have already discussed that self-organisation is a conditio-sine-qua-non in highly complex systems to survive. But let`s discuss the supply chain coupling, which is subject to operational supply chain controlling in more detail. Moreover, let`s better unterstand why the (self-) coordination in an agile fashion is asking for a digital twin of the supply chain.

Figure 5.1 Change profile of supply chain coupling (based on Weber 1992, further developed by Wehberg 1994)



In principle, supply chain controlling can make use of exactly those coordination mechanisms in the course of system coupling that are also used for coordination tasks in the execution system (Weber 1992). This is essentially the coordination via personal instructions, through programs, plans and finally via self-coordination. Figure 5.1 shows the change profile of such supply chain coupling.

Self-organization uses its possibilities by effectively and efficiently linking the subsystems of a supply chain (management). Self-organization is characterized by its recursive, autonomous, redundant, and self-referential attachment (Wehberg 1997):

- Recursive because certain characteristics of digital supply chains are similar on different factual hierarchy levels, i.e. recurrent. Such characteristics are not limited to the organization, but can include goals, functions, methods, instruments etc. For example, modular structures can help to ensure the communication and compatibility of various units ("plug-and-serve").
- Autonomous, because to a certain extent a digital supply chains manages or develops itself and seeks its own way for this, without there being a central unit for it (e.g. as a self-controlling drone). Controlling and controlled unit are then one. At the same time, many units, so to speak, can perceive the control or development by a "swarm". Then, the control intelligence is also "swarm intelligence".
- Redundant, because in principle those units of digital supply chains have a controlling or developing influence, each of which has (most or best) information. This means that fundamentally control-relevant information is available and shared for all relevant units.
- Self-referential, because the behaviour of a digital supply chain always reacts back to them and these feedbacks in a way form the basis for further behaviour. Accordingly, the system or its units themselves in part produce those characteristics that make up the system. The cause and effect merge into each other. Development in small steps and avoidance of oversteer are then required.

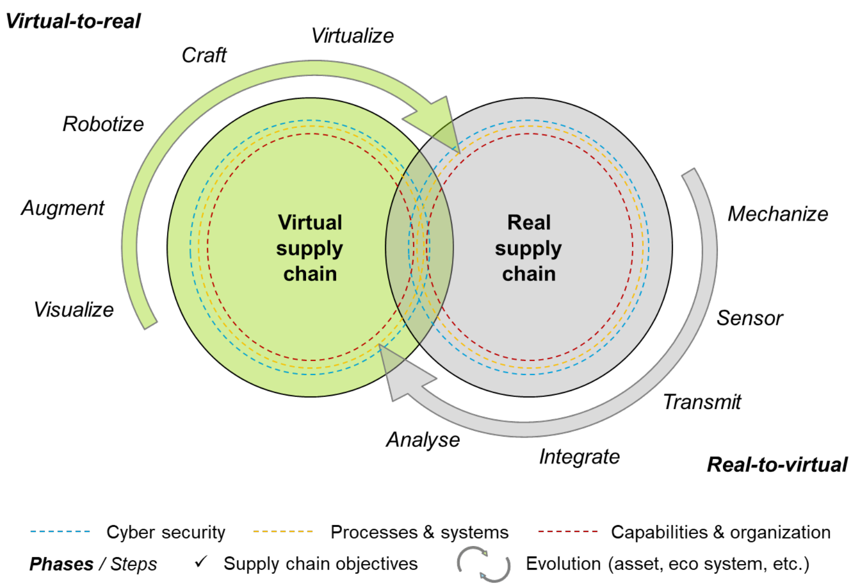
Self-coordination corresponds to digital supply chains insofar as it is based on its methodological or technological foundations and vice versa. In this context, the varying character of self-organization suggests that the suitability of these coordination mechanisms also depends on the complexity of the supply chain relationships. Here it is, where the digital twin of supply chain come into play.

5.2 Mastering the digital twin

The digital twin of the supply chain helps to coordinate and develop relevant relationships. Since the relevant relationships can be very multi-layered, especially in the course of digitalization, self-corrdination requires appropriate instrumental support. The positioning of the relevant interfaces in a corresponding **relationship portfolio** makes it possible to derive design implications against the background of the company-specific situation. Current and potential supply chain relationships must be evaluated with regard to their significance for the long-term viability of the company. At this point, the distinction between critical, reactive, active and inert relationships is helpful (Probst/Gomez, 1989, Vester 1990, Wehberg 1994). The relevant elemements are being captured by the so called **digital twin of supply chains**, which will be explained in the following:

How does the digital actually twin work? Critical system elements that exert a strong influence on third parties and at the same time are themselves subject to strong influences must be given high attention by the supply chain management. The digital twin of supply chain models relevant elements and its behaviour (Figure 5.2.). It builds an optimization loop of two phases, **real-to-virtual** and **virtual-to-real** in order to measure, understand, enhance and monitor the performance of supply chains. Specifically, the two phases of a digital twin summarize a road map of 10 key milestones, where the progress from one milestone to another marks the achievement of specic supply chain objectives, and puts cybersecurity and digital traits at the core. Although the digital twin technically completes at milestone 10 for a relevant supply chain element – like a logistics asset or operation - it must be broadened and started again to include a wider set of supply chain elements, assets or business segments, the entire organization and, ultimately, the end-to-end supply chain of a company, including external stakeholders. A comprehensive cyber risk management initiative that is secure and resilient as well as an culture that would enable the evolution of the supply chain remain at the core of the digital twin.

Figure 5.2 Digital twin of the supply chain



Does the classical decision theory match with the requirements of a digital twin? In connection with the coordination decisions aimed at supply chain coupling, it is now also important to satisfy the holistic-evolutionary or resilient understanding of supply chain management and thus the process orientation in the broader sense. This is because interface management is directed against and even justified by isolated and mechanistic ways of thinking and acting. To this end, it is necessary to fall back on **decision-theoretical principles**. The classical decision theory models the business management decision field in the core on the basis of the so-called result matrix, which distinguishes an action (among other things functional and basic strategies), a state and a result space (target system) and can be more or less differentiated by the consideration of risk and uncertainty (Bamberg/Coenenberg 1991). It implicitly assumes that the elements to be assigned to the action and state space are exclusively influencing, i.e. active, elements and that the elements of the result space are exclusively influenced, i.e. reactive, elements. The decision maker himself stands above the system and "pulls the strings".

What kind of theoretical basis fits the digital twin? Apart from the fact that the separation of decision maker and decision field does not take into account the operational unity of the supply chain, it must be critically stated with regard to the decision theory described here as classic that in reality such a clear distinction between active influencing variables and design parameters as well as reactive target variables will only be possible in a few cases and thus equates to a certain trivialisation. Rather, reactive, active, critical as well as inert elements can be inherent in the so-called action as well as result and state space and play a decisive role in the overall context. Thus result variables can be quite active, critical or sluggish in nature. Numerous framework conditions can also be influenced. It should also be remembered at this point that the "**butterfly effect**" stems from chaos research, which emphasises that even small influences (butterfly strike) can have serious consequences (hurricane) due to their networking (e.g. Küppers 1993). The boundaries between action space, state space and result space become blurred. Instead, the distinction between endogenous system variables, on which direct influence can be exerted, and exogenous variables, on which indirect influence can be exerted at most, is appropriately made. The decision maker, who himself is usually a critical element of the system, now has to consider the entire in- and surrounding system as well as their networking. In summary, this suggests a new decision theory, which places the classical decision model on a cybernetic-systemic basis. The **behavioural decision theory** (Berger/Bernhard-Mehlich 1995), for example, can be understood as a first approach on the development track of such a New Decision Theory. And also the system methodology of Gomez 1985 is to be classified here. It satisfies the demands of process orientation in the broader sense.

The supply chain coupling as well as the supply chain formation have so far been examined primarily from a static point of view. However, supply chain relationships evolve over time and can therefore only be coordinated from a dynamic understanding, especially in the course of digital supply chains. This means that changes in the change profiles are also left to supply chain management. In the following fourth part, the dynamics of digital supply chains will therefore be discussed in more detail. First, typical development paths have to be categorized before the associated structural dynamics can be dealt with in more detail.

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Part 4: How to develop digital supply chains

1 Typical paths of supply chain evolution

Supply chain development is the qualification of structural changes over time. It is an integrated part of the development of the company and is ultimately expressed in the fitness of supply chains, especially in the development and maintenance of success potentials (in the following: Bleicher 1992, Göpfert/Wehberg 1996 and Wehberg 1994).

1.1 Trend-sonar digital supply chains

The supply chain development is characterized by its dynamic plant. It offers managers an important orientation aid, especially in turbulent environments. In this respect, it can be understood as the reference point for supply chain management. To the extent that the supply chains aims at a certain development through its own addition, which means it tries to develop itself, supply chain development takes on an object character. It is then the result of **innovation** efforts and underlines the autonomous character of supply chain management. Companies that are pioneers in the implementation of digital supply chains take on a certain market maker function and set new standards in competition.

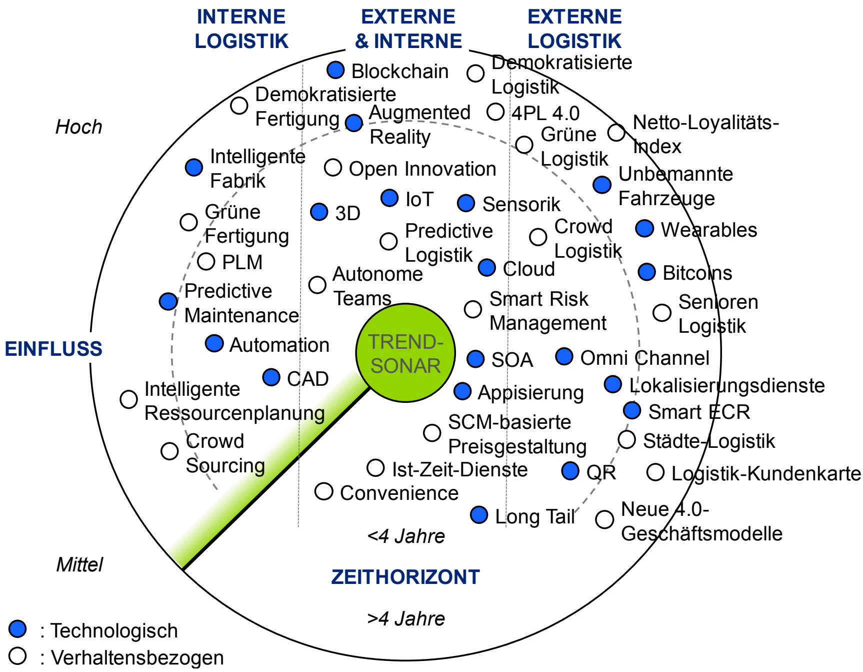
If, on the other hand, a supply chain is confronted with an obligation to adapt, the development becomes a regulator of supply chain management (similar to Kirsch et al. 1979). In this case, the company is a market taker and must adopt new standards in order to keep pace with the competition. The fact that the development of a supply chain is only "feasible to a limited extent" or cannot be completely mastered repeatedly results in deviations between the actual and desired development of a supply chain and thus in adjustment requirements. Overall, supply chain development is therefore a **co-evolutionary** process, i.e. supply chains and surrounding systems develop together.

Trends such as **digitalisation**, which have a significant influence on the supply chain of the future, are a trigger for its development. For the practitioner it is not sufficient to understand new developments at a high aggregation level as a megatrend. In order to assess the influence of a trend and, if necessary, derive options for action, a more differentiated discussion is required at the level of concrete technological and behavioural trends. The latter can result from the behaviour of market participants or - more generally - from social behaviour. The **trend sonar** presented in Figure 1.1 provides an example of selected supply chain trends in the course of the fourth industrial revolution (see also the trend radar by Bubner et al. 2014). The sonar looks, so to speak, beneath the surface of the water in order to detect not only the tip of the iceberg, which is the obvious. Even a captain needs detailed information about the best way to navigate his ship in order not to be shipwrecked, to use this metaphor. Examples of individual waymarks or trends make the discussion tangible:

- **4PL 4.0**: The EU logistics project aims to improve the interoperability of logistics companies of various sizes and the competitiveness of Central European logistics hubs.
- **Real-time services**: Agheera offers innovative sensor technology and portal solutions for real-time tracking of shipments.
- **City logistics**: The Dutch inland-city service offers urban consolidation centres in 15 cities.
- **Omni Channel**: The service provider Hointer combines real with virtual shopping experiences through the on-site use of eTags with personalized content.
- **Crowd Logistics**: DHL MyWays connects individuals for last mile delivery.
- etc.

The trend analysis in the form of the trend sonar provides a basis for any discussion on the development of supply chains (Figure 1.2). Such discussion typically has to be sector- and company-specific because the influence of certain trends always has an individual character. And it provides the basis for concrete innovations, just because shaping the future requires an alternation of change and stabilization. Corporate supply chain managers must ask themselves how they can effectively organize suitable **scouting** of new trends if they do not want to be surprised by one or the other supply chain innovation. Especially in times of digitalisation, supply chain development is a question of innovation with regard to individual processes, operations and business models.

Figure 1.1 Trend-Sonar (similar Bubner et al. 2014)



As already mentioned, it can be assumed that change and stability cycles alternate in the course of supply chain development. This does not mean that the character of a digital supply chain is episodic. Rather, a development in the direction of a digital supply chain will take place in batches with **stabilizing intermediate phases**, each of which corresponds to a higher order. The change towards effective, market-driven structures and the efficiency-enhancing stabilization typically alternate.

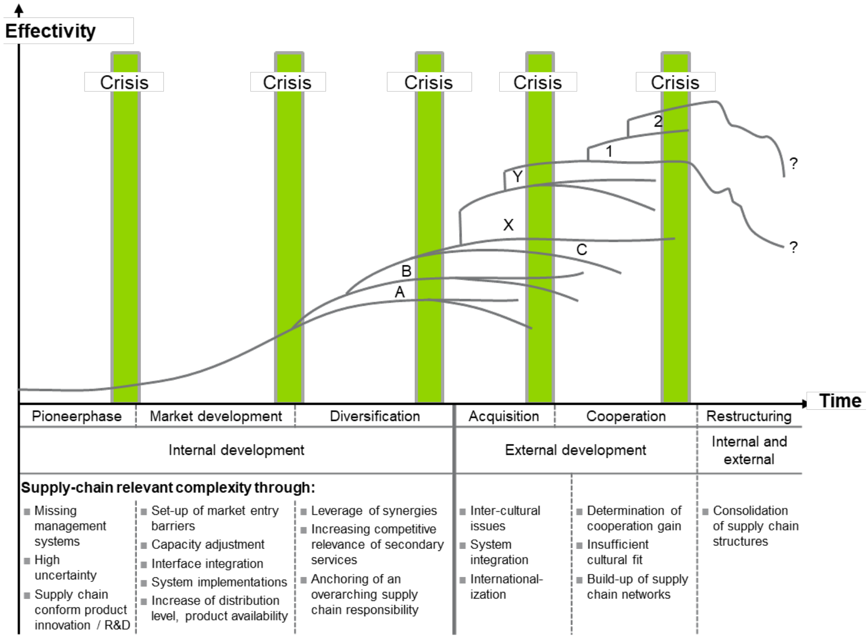
Before such an interplay of a supply chain between stability and change orientation is to be examined in more detail, it seems appropriate to first answer the question of whether there are any **ideal-typical development paths** at all in which such a system behavior of supply chains moves - paths, in other words, that supply chains repeatedly follow in an exemplary manner. The knowledge of such dynamic patterns offers a "conceptual overall view" (Kirsch et al. 1979) for the treading of existing paths, but also for the creation of new development paths.

A prerequisite for the invention of new development possibilities, however, is the ability to engage in a corresponding "**fundamental critique**" (Kirsch et al. 1979), which characterizes the questioning of prevailing contexts. This requires problem views of supply chain management and confrontation with alternative contexts. What do these development paths look like now? In other words, which phases can be used to describe supply chain development? It will be explained in the following in its economic and technological dimension (for the dimensioning of logistics see Wehberg 1997).

1.2 Market development and supply chain evolution

The phases of the economically induced supply chain development can be illustrated by following Bleicher's model for corporate development (Göpfert 2013, Wehberg 1997). It is also conceivable, however, to make other life cycle concepts "fruitful" for modelling supply chain development. Pümpin and Prange (1991) offer here a systematic overview of the models of corporate development that can be found in the literature. If we now take up the construction of Bleicher, we can sketch an ideal-typical supply chain development divided into **six phases**, which is shown in Figure 1.2 in its overall view (Bleicher 1991 and Wehberg 1994).

Figure 1.2 Phases of supply chain development (based on Bleicher 1992, changed and completed)



In the **pioneering phase**, the development of the company is based on an innovation. The way the company thinks and behaves is therefore strongly influenced by the inventor, who is often identical with the owner (continued by Pümpin/Prange 1991). And also the employees of supply chain management are fixed on the model of the pioneer company. The service repertoire concentrates on a market niche or on a relatively narrow sales programme for which new logistics channels have to be established. Success is measured primarily by technological and market parameters rather than financial ones. Technical start-up problems, e.g. of packaging machines, can stand in the way of high supply chain efficiency. In addition, due to the absence of management systems, the operational process is controlled primarily through on-site information, personal instructions and improvisation. Information logistics is accordingly isolated. Furthermore, the often weak capital resources of pioneer companies result in the particular necessity that supply chains, especially through appropriate postponement strategies and the reduction of inventories, contributes to the reduction of capital tie-up. Furthermore, due to the high risk appetite and insecurity of the pioneer business, the supply chain structures must be planned open to use (Wehberg 1994), which means they should be able to offer a rather broad range of services and sufficient capacity reserves.

As the volume of services increased, the improvising behaviour of the multinational company was increasingly unable to meet the supply chain requirements. The integration of the flows of goods and their stronger orientation towards market events are becoming the focus of interest here. The transition from the pioneer phase to the market development phase in logistics is particularly likely to be marked by the following **signs of crisis**: Inadequate competence of supply chain management, non-existent technical systems of information logistics, technologies that have not been tried and tested to a great extent, overstraining of capacities through reworking, flow structures that have not been adapted to the needs of the process because they have evolved over time, as well as logistical inadequacy of product characteristics. The aim of the company in such a situation must be to create the economic conditions for handling supply chain problems through the broader diffusion of its product.

In the course of the **market development phase**, the company opens up broader customer groups, which go far beyond the originally worked market niche. The buying of further owners, which is often accompanied by growth, can justify a corporate culture that is now less focused on a single person. In order to secure the company's growth, barriers to market entry must be created. Logistics-induced barriers to entry can result, for example, from the occupation of certain distribution channels through exclusion contracts with sales agents. The realisation of a price advantage within the framework of penetration strategies also offers corresponding starting points. The capacity adjustment of logistics resources primarily involves the specialisation of the range of services with simultaneous flexibilisation of the application potentials (as to the resource strategy of Logistik Wehberg 1994). Solution-oriented learning strategies are used for this purpose. Only product changes, the main cause of which is to be seen in the attempt to further differentiate oneself from imitating competitors, counteract the specialization of the service spectrum. The capacity adjustment in the supply chain is also aimed at preventing losses in market share due to inadequate readiness to deliver. It is thus the central bottleneck factor for the company.

In order to counter the risk of the top management being overburdened by operational activities, it is particularly incumbent on the cross-divisional function of supply chain management to coordinate the interfaces with the functional organization typical of a growth company. Due to the increasing size of the company, the coordination of performance activities is increasingly determined by programs and plans rather than by personal instructions. The **crisis potential of growing companies** is much smaller than that of pioneering companies. Nevertheless, mistakes in adapting to possible growth, for example through the realization of so-called "lost sales", can offer the competition opportunities for market entry and thus jeopardize the development of the company as a whole. And also the development of logistical overcapacities (for the use of experience effects) as well as the neglect of new success potentials hold a high crisis potential of the market development phase, which introduce the diversification phase.

In the **diversification phase**, the company or logistics applies its previous experience and know-how to new technological and/or market areas in order to exploit synergies in the further development of the company and to create a risk balance between the areas of application that arise. In supply chain management, examples are the transfer of knowledge from supply logistics to waste logistics and the implementation of supply chain principles in research and development. If fields of application are developed that do not show any relationship to the previous ones, the new self-image must be incorporated into the philosophy of supply chain management or the company. The differentiation of the company in terms of performance policy can be seen not only in the diversification of primary benefits in kind but also in the corresponding refinement of secondary logistics services. If one considers that the company's product offerings in this lifecycle phase are largely homogeneous in relation to the competition, it is precisely the differentiation of logistics services that offers opportunities for profiling in competition. Delivery service and environmental compatibility in particular should be mentioned in the first place. Although digital supply chain can in principle play a role in any other phase, it is therefore particularly relevant in diversification. In such a situation, the development of a supply chain tends towards self-controlled, flexible structures in which the synergy of supply chain activities, such as the bundling of goods flows or the realisation of paired transports, must be taken into account by decentralising and self-coordination.

Above all, the **crisis potential of diversifying activities** lies in the lack of realization of synergies between the existing and newly added logistics services, but also other corporate functions. The higher order of digital supply chains, for example, must lead to concrete customer and efficiency advantages for the company in order to be sustainable. Simply being more complex, more flexible and technologically up to date has no value for the company. The ideal way to manoeuvre out of such crises is to develop external opportunities, which means to exploit the potential of other companies through appropriate acquisitions or cooperations.

The **acquisition**, i.e. the takeover of companies, represents a first opportunity for the external development of a company or supply chain in particular. If the company in question sees the takeover not only as a financial investment object but also as an attempt to supplement its own portfolio of services, regions and resources with the acquired business, the extent to which synergies can be exploited depends to a large extent on the extent to which the parties concerned are compatible with each other in the sense of a committed reorientation. Particularly in the case of mergers, the corporate cultures that have grown differently must be brought closer together and the new ways of thinking and behaving must be stabilised. With regard to the supply chain subculture, the core of such an acculturation can lie in the harmonisation of different competence levels. Possibly, for example, in the context of the takeover of Rollce-Royce by the BMW Group, the British advanced supply chain expert had to be introduced to the Bavarian supply chain professional. Depending on the degree of integration sought between the acquired and the parent company, the technical supply chain systems will also have to be aligned. The possible **crisis potential of acquisition efforts** thus lies above all in a lack of integration. In order to overcome the crisis - true to the motto "if you can't beat him join him" - a cooperation relationship can be entered into.

Similar to acquisitions, **cooperations** also aim to complement the service, regional and resource portfolios appropriately. However, less adjustment pressure can be exerted on a cooperating company than on an acquired one, so that within the framework of the cooperation phase there is considerably less "compulsion" to realise a cultural fit. In the cooperation phase, supply chain management tends to change-oriented behaviour patterns, especially if the gain in cooperation results from the synergies of flexible network structures. However, management profiles that are also geared to change are also necessary if the cooperation is to be regarded as having failed. In this case, supply chain management is confronted with a complete reorientation or restructuring of the normative, strategic and operational areas in order to enable their further development.

Finally, during the **restructuring phase**, supply chain management is attempting to open up new options for its development and for the development of the company in general - virtually by jumping into one of the aforementioned phases. If the company does not succeed in tapping new potential through appropriate restructuring, its existence will be endangered. In the course of an external "development", the company in question may then be taken over by others.

1.3 Technology development and supply chain evolution

Technology-induced supply chain development characterizes the qualification of the technologies used in supply chains over time. It is the result of technological progress and innovation strategies in supply chains in particular. In order to understand the dynamics of supply chain-relevant technologies, their development can be described using the S-curve concept known from innovation research (Krubasik 1988 i.V.m. Wehberg 1994). The starting point of this concept is the consideration that for every technology used in supply chains and the services provided with it there are certain performance limits that cannot be overcome. Once this limit has been reached, there is no further development, i.e. improvement, in all supply chain management efforts, unless the technology concerned is replaced by a new, more efficient one. For supply chain management it is therefore important to recognize the **weak signals of possible replacement technologies** from the corporate environment at an early stage and to transfer them into the company's own supply chain in good time. Substitution technology can, however, also be the product of the company's own innovation efforts.

The ideal-typical course of technology development describes a path from pacemaker to key to basic technologies. Basic technologies mark the end of the **S-curve**. They are therefore particularly endangered by new key technologies. The latter are characterized by high competition relevance because they are not yet standard, but on the other hand, unlike pacemaker technologies, they already offer a high performance potential. Digital supply chains and the technologies associated with it (cyberphysical systems, clouds, predictive data analysis, etc.) are key for supply chain development in this sense. Their **degree of maturity from a technological point of view** can also be classified on the basis of the following levels, which also correspond to the competence types presented in the chapter on learning strategy (similar to acatech 2015, Wehberg 1997):

- **Pre-mature**: No use of cyberphysical systems or similar in the supply chain.
- **Digitally-interested**: Selected features like configuration and maintenance of the supply chain are digitally enabled.
- **Digital-beginner**: Condition-Based Tracking provides supply chain transparency.
- **Digitally-forward**: Supply chain analysis and foresight offer selected benefits.
- **Digital-professional**: Integration into the core business of an end-to-end sup-

ply chain.

- **Post-digital**: Supply chain facilitates intelligent services and business models.

As already mentioned, digital supply chains should by no means be limited to technological dimension. The use of new technologies is a necessary prerequisite because it enables decentralized control and self-coordination. The effective use of digital supply chains also requires a holistic, coherent overall concept that takes all other dimensions of supply chain development into account. In connection with the technology life cycle, Bauernhansl (2014), for example, also proposes the **product, factory and order life cycle** as relevant classification criteria for the chronological sequence.

Overall, the description of the supply chain development makes it clear that it may well take on a life of its own in relation to the company's development, or even become the **'motor' for the company's development**. For example, supply chain management can enter into cooperative obligations to establish a network, while the company as a whole is characterized by growth phenomena. The presented ideal type of supply chain development as an integrated part of company evolution must therefore always be critically questioned. It must not restrict the creativity of supply chain management in the search for new development paths.

1.4 New business models and digital supply chains

The discussion of aforementioned maturity levels shows that new business models prove the highest maturity and offer the largest potential. Supply chain management itself can be subject to such new business model development if logistics is the core business of the company or logistics service provider. On the other hand, digital supply chains are a key enabler for new business models in the manufacturing industry. In both cases a comprehensive journey for a business led technology transformation is vital for the success of the digitalization strategy of the company, combining business and technology perspective.

Regardless of who has the best prerequisites to establish themselves as a post-digital leader and which functions are affected, digital business models are generally characterised by (some of) the following **key characteristics** (Anderson 2007 and 2012, Reichwald / Piller 2009, Wehberg 2015), which can also apply to digital supply chains:

- **LaaS**: Logistics as a service has its intelligence in the cloud, so that the control algorithms are not revealed by its sole use.
- **Combination of software and hardware**: Proprietary hardware solutions can represent market entry barriers that support the achievement of critical sizes, e.g. corresponding service platforms.
- **Knowledge as new core**: Through "sharing" and accumulation of empirical knowledge, comparative competitive advantages (USP - Unique Selling Proposition) are created, not necessarily through patents. Knowledge is only created through the application of the right algorithms, i.e. not through the accumulation of data itself.
- **Long tail**: Logistics for niche products in the sense of Anderson (2007) can in sum be profitable business. The definition of the niche can arise from the needs of the primary (product) and / or secondary service (logistics) (for details the triple-long-tail strategy see Wehberg 2015).
- **B2B follows B2C**: Examples for suitable business models come in particular from the B2C sector, because here data security is less problematic and the variety of ideas broader, so that appropriate scouting of ideas makes sense. In the area of digital business model innovations, the B2B area follows the B2C area. At the same time, many B2C business models are still looking for their economic basis. An economic benefit in the B2B area is often more likely to be realized, which also explains the disproportionate growth of this area.
- **Democratization** of logistics: In extreme cases, logistics solutions can be offered for everyone, which means the "Maker" initiative by Anderson (2012) can be transferred from production (e.g. 3D) to the supply chain function (e.g. crowd supply chain management), including the sales function (e.g. Omni Channel) and so-called open innovations in the sense of Reichwald and Piller (2009).
- **Freemium**: The market penetration of many new digital business models is driven by the fact that certain basic services are offered free of charge, while additional services with additional benefits are invoiced.

Specifically, new business models in the logistics service provider market are likely to be driven both internally, which means by participants in the logistics market, and externally, i.e. by market convergence. Practice will show in the coming years which models will prove to be particularly competitive.

1.5 LogTechs - start-ups in the logistics service provider market

Over the course of the last five years there has been a significant push of Supply Chain Management & Logistics related to the market, so called LogTechs. For decades the **logistics industry** has been dominated by giants like UPS, FedEx, or Deutsche Post DHL. These players typically have a proven, holistic offering that covers a variety of integrated services along the global supply chain. In addition, they regularly act as an integrator that accumulates resources, capabilities, and technologies to provide comprehensive solutions to customers. As a result, they now house a huge number of employees globally, high market shares and a significant market capitalization. Economies of scale – secured via scaled assets - has been a key competitive advantage that is typically raising large entry barriers to new players in the market. This is changing now (hereto and in the following Buchholz / Wehberg / Zimmermann 2017).

Asset-light business models

Technological advances, increasing levels of connectivity, industry convergence and digitalization are disrupting the logistics service market. Emerging LogTechs are leveraging these trends and often have an internet-of-things (IoT), analytics or digital related background. Their business model typically builds upon a agile, asset-light, technology driven backbone, allowing them to reach scale and often even grow exponentially with a very lean infrastructure and at limited risk. Uber and AirBnB are two prominent examples that illustrate that exponential growth is not tied to the amount of capital. This principle seemingly starts to extend to industries such as the logistics service market as well.

At the same time, **customer expectations** in the logistics service market are continuously on the rise - convenience besomes key. Ever faster delivery times, ongoing price optimization and higher flexibility in terms of modes, pickup locations, or specific delivery slots are expected. This is driving demand for innovative and specialized solutions, especially in the urban delivery and medium-haul market. Often young LogTechs can take better advantage of their lean structure and slim in coming up highly targeted. Such start-ups often are innovative and customized supply chain firms compared to their more traditional peers, which sometimes lack the flexibility and speed in responding quickly to changing dynamics and new technology.

Over the last ten years, there has been a significant increase in the number of

LogTechs. Correspondingly, the amount of investment deals and related company valuations has been raising. For example, more than 5 billion US dollar **venture capital** were invested in LogTechs in 2016.

Recent surveys of LogTechs founded reveal that three quarters of the number of LogTechs had been founded only within the last five years. The majority are located in **North America**, along the typical start-up clusters in Silicon Valley, New York, Atlanta, and Chicago. About one third are based in Europe, the Middle East or Africa. Within this region, **Germany** can be seen as key market. A number of LogTechs have been founded in the country over the past ten years in cities like Berlin, Munich, Cologne and Hamburg. The companies average headcount ranges between 50-100 employees.

The go-to-market strategy of LogTechs often represents an "unbundling" of supply chain services. A number of LogTechs provides a number of services across multiple customer segments. But the majority takes a much more **focused approach** to offerings and concentrates on providing a very specialized type of service. This is a major difference to the more integrated business models of traditional logistics service providers. Nonetheless, large parts of the physical transport of goods remain with established players, as they own the assets required to execute deliveries. LogTechs thus own and develop an increasing share of the customer interaction, rather than disrupting the entire value chain at once.

Let`s look at some examples: A large number of LogTechs focuses on freight brokerage, last mile delivery, convenient solutions and supply chain analytics. A few examples will illustrate their innovative, very distinct offerings. Companies like **Flexport**, **Haven** or **Roadie** operate platforms for price comparison and booking services for freight shipments. LogTechs such as **Postmates**, **Flirtey** or **Rickshaw** focus on short distance transport in metropolitan areas. Their offering is to secure the urban logistics within a few hours via either courier, drone or self-driving robotic vehicles. **InstaFreight**, **Shyp** or **Swapbox** provide combined easy-to-use services incl. pick-up, packing, labelling and warehousing. This is often going along with an e-commerce solution. Route optimization, tracking of shipments and other analytics belong to the offering of firms like **Routific**, **Supply Vision**, or **OptimoRoute**.

Most of these LogTechs do have a digital footprint with elements of IoT, connectivity, analytics, mobile apps or easy-to-use web portals. They typically have three major **advantages** compared to their more traditional peers:

- LogTechs operate with **asset-light** or in some cases asset-zero infrastructure and corresponding business models. Making use of new technologies, they challenge historic assumptions of the logistics market.

- While creating online marketplaces, interfaces, and dashboards, they effectively connect the demand with the supply side. Hereby they gain **ownership of the customer interfaces** via customer data, and further supply-chain transparency.
- Eventually, their “**post-digital**” character more naturally embraces lean structures and a resilient working style. This leads to a very high degree of agility and flexibility when working with customers and serving customer needs.

Typical LogTech clusters

Analyzing a number of LogTechs allows to identify typical clusters of business models and customer segments. A significant proportion of LogTechs focuses on providing “on demand” **brokerage platforms**, single market places or bundles of multiple market places. These typically enable customers in bidding and bargaining for the best option in terms of transportation modes, etc. An example that very well illustrates this cluster is the firm Transfix. It provides a brokerage platform that facilitates smaller logistics companies and individual truck drivers to offer free capacities on a digital market place. The most significant benefit brokers or aggregators typically provide is to create greater, real-time transparency with respect to rates and logistics options along the long-tail of demand and supply.

Another significant cluster of LogTechs provides **supply-chain analytics**, ranging from descriptive analytics (e.g. better visualization of data), KPIs and dashboards towards advanced analytics solutions. ShipHawk e.g., promises to enhance buyer experience, logistics automation, and shipping intelligence. This is managed by sumarizing more than 200 delivery options and rates in a cloud solution. The company analyses spend and shipping performance by carrier to give advice that how to optimize packaging strategies and profitability. LogTechs in the segment of “Analysts” typically focus on increased transparency, simplified workflows, and better decision-making for customers to handle their orders.

A third cluster of LogTech business models is the **niche player**. These firms usually provide a one-stop-shop solution for selective customer segments or within a limited regional coverage (often focused on major metropols). Shyp, as example, integrates its solution into customers’ fulfillment operations. It provides carrier comparison services, labelling printing, pickup, and packaging support that can be integrated into existing e-commerce solutions. The company’s pickup and packaging offering concentrates on major cities in the USA. Pricing models change dependent on the number of shipped items per month. Such niche operators provide an increased level of flexibility in payment modes (e.g. switching on-demand or subscription models) and response cycles towards changing customer needs.

Last but not least, a fourth business model cluster of LogTechs acts as **technology provider**. Firms in this space typically develop and market technology that bridge a gap between traditional customers and logistics service providers. Cardrops is one example company of this kind that sells and installs small hardware devices in an end-user’s car. The technology allows logistics partners to remotely open cars’ trunk and deposit deliveries. Moreover, the start-up collects mobility data through their device and conducts analytics in order to improve delivery slots and locations over time. Companies in this cluster are innovators at the very heart of the industry. They target at holistically disrupting the modes of transportation or types of packaging and improve the customer journey or cost efficiency.

The climbing number of agile LogTechs might easily be perceived as a threat by established players as well as overwhelm customers with the sheer number of new names and offerings. Nonetheless, upcoming LogTechs equally offers plenty opportunity to both groups alike. Established logistics service providers as well as industry firms can benefit from this development by **leveraging new business models** via proper collaboration, incubation, investments and acquisitions.

Beyond the modeling of the life cycle phases of the various logistics dimensions, it can be assumed that there are generalized, i.e. phase-independent characteristics for supply chain development. In the following, these are to be worked out against the background of its evolutionary theoretical foundations.

2 Key principles of supply chain evolution

For the foundation of the dynamics of supply chains, one can refer to corresponding approaches of organizational theory. These approaches suggest design principles, which offer assistance to handling complex supply chain phenomena and digital supply chains in particular. All approaches have in common the assumption of limited information and processing capacity as well as "blindness ", i.e. cannot be planned synoptically.

2.1 Perspectives of organizational theory

Industry perspective

One approach to describe, explain and shape the structural dynamics of industries, i.e. entire classes of organisations, is the "Population Ecology Approach" (Hannan/Freeman 1977). The most important **representatives** of this approach include Hannan and Freeman as well as Aldrich, Kaufman and McKelvey. These authors are particularly concerned with transferring the mechanisms and taxonomy of the evolution of biological systems to social structures (in the following, for example, Semmel 1984 and McKelvey 1982):

The central concept is the **population**. It is a polythetic group of organizations that have largely similar basic skills, so-called "comps," to ensure their existence. The sum of all comps of an organization indicates the "genotype". The similarity of **genotypes** stems from the fact that all the members of a population fall back on a common repertoire of population-specific knowledge and skills, which is also known as the **compool**. From the common source of basic skills, similar appearances, i.e. structural forms of the organizations of a population, called **phenotypes**, regularly follow. The population-specific organization can therefore be understood from two different perspectives, on the one hand by describing the phenotypic forms of expression and the genotypic conditions that explain them on the other.

In order to understand the long-term change of organizations in a population, it must now be taken into account that both phenotypes and genotypes are influenced by their environment. The **environment** is to be understood as a set of external forces that impose constraints on an individual organization or a population and are outside its ability to influence them (McKelvey 1982). In interaction with the environment of individual organizations, a change in the phenotypes and genotypes of a population occurs. The **mechanisms** include, in particular, variation, selection and preservation (Aldrich 1979, Hannan/Freeman 1977, Kaufman 1975, McKelvey 1982, and others).

The application of population-ecological fundamentals to supply chain management leads to the following picture: The consideration of entire classes of logistics systems is in the foreground here, for example to the CEP services market. From a population-ecological point of view, all logistics-related competences together characterise the pool of the population. The development of supply chains is attributed above all to the evolution of its basic skills (genotypic concept of supply chain) and structural forms (phenotypic concept of supply chain). This also and especially applies to digital supply chains. For example, the diversity of supply chain variants takes into account the need for resilience, which is derived from the **inertia** of supply chain structures. In many cases such structures cannot adjust as fast as environmental changes occur (for further analogies see Wehberg 1997).

Population ecology records the development of entire industries. The logistics sector will make use of the opportunities offered by Logistics 4.0 and the new business models and services associated with it, as the following case illustrates:

Project example: Smart logistics services (acatech 2015, translated)

"The economic environment of internationally operating seaports is characterised by global competition, high cost pressure and great dynamism with regard to the actors to be involved. The pressure on the port infrastructure is growing (increasing freight volumes with little scope for physical expansion).

Individual players use smart processes and partial infrastructures, but there is a lack of optimisation of the overall system. The cooperation of the actors, such as port management, shipping companies, operators of container terminals, logistics network operators, forwarders and railway companies takes place only on a bilateral basis. The most important drivers for an increase in efficiency and effectiveness on the basis of intelligent, data-based networking are:

- Inefficiency in transport operations due to long downtimes of vehicles in port

- Strong increase in traffic with limited infrastructure growth (port can only grow geographically to a limited extent)

- Demand for intelligent goods and order tracking in global supply chains

- The need to link goods with traffic flows in supra-local transport infrastructures

- Increasing importance of smooth and time-saving container handling

- So far only limited picture of the traffic and infrastructure situation for decisions (marketplace/ecosystem)

(...) A synergetically designed Smart Services system designed for the interaction of port operations in a dynamic business network contributes to the overall optimisation of port infrastructure utilisation. The key performance indicators (KPIs) of the individual operations can be mapped, the port ecosystem as a whole can be improved and economic benefits can be generated.

Smart Services enable port operators, service providers and transport and logistics companies to place their own transport orders in real time, the aim is to monitor media and routes in order to transport goods more efficiently and safely and, as a result, to increase the satisfaction of all parties involved, in particular end customers."

"The implementation of Smart Services takes place through the processing of own, external and reporting data. Data protection requirements are controlled by access regulations and personal characteristics. There are different data providers depending on the seaport. Local business partners for Smart Services are taken into account by an activation and deactivation concept and can be integrated as required. Participating business partners and authorities receive a real-time and forward-looking view of the respective status of the infrastructure used (roads, bridges, waterways) and the resulting resource requirements. Marketplace mechanisms are used to lay the foundation for the self-sustaining expansion of this approach into a port ecosystem that includes other related businesses. IT-technically, functions will be combined that are currently offered in isolated web portals and smart device apps. They are easy to use for all players as software "as a service" offerings. Each participant can share information and services with the other network participants at flexibly definable conditions and benefit from them. Through a smoother processing of traffic and goods flows in the port and beyond, inter- and multimodale logistics chains can be closed in a service-oriented way, thus enabling further innovative business models.

(...) The economic ecosystem in seaports is characterised by different actors whose interaction is necessary in order to achieve efficiency gains in container handling and traffic flow. In the value creation network, the seaport operator assumes the task of port management. He is responsible for official matters, port communication, water and land infrastructure, road and bridge network as well as the safety of ship traffic and real estate management.

Other important roles are: Container terminal operators (...), hauliers (...), parking providers (...), business network operators (...).

(...) The overall optimisation of logistics processes (from port logistics to the destination of the transported goods) is the common benefit for all players (also in Smart Cities/Smart Countries). It is an overall logistics concept that can be transferred and extended to any logistics hub, such as airports or freight stations, in addition to seaports. The decisive factor is that the individual value propositions are sufficiently relevant for each actor; only if all actors along the transport chain use the Smart Services and contribute their share of the required data can the overall benefit be achieved. A gradual expansion based on the principle of a service marketplace will continuously create new added value for the various user groups."

Corporate perspective

In contrast to population ecology, the so-called **organizational process approach** brings together a group of scientists who, in the context of their numerous publications, have endeavoured to shed light on the processes that take place within organizations by transferring evolutionary theoretical findings (in the following, Semmel, 1984 and Wehberg, 1997). It therefore directs its efforts above all to the level of the individual enterprise. This group includes Bigelow, Röpke and Zammuto, but also Dyllick and other organizational theorists.

At the center of the organizational process approach is the effort to gain the deepest possible understanding of the three mechanisms of evolution within goal-oriented social systems. A peculiarity of this approach is that it does not want to understand the evolutionary phenomenon to such an extent that it is restricted to certain facts, like the genotypes and phenotypes of a population. Thus, it basically includes all levels within a factual-hierarchical organizational system, for example the organization as a whole, subsystems, etc. (similar to Semmel 1984) Instead of the term hierarchy, the term "**recursion**" is also used if the different hierarchical levels of a system assuming they are similar with regard to certain structural properties (Bleicher 1995).

The integration of the organizational process approach and supply chain management leads to a focus on populations of variants, which can also address certain behaviors (such as disposition practices, warehousing principles), ideas (process innovations) and other artifacts of individual supply chains.

The inclusion of the respective higher level in the objective hierarchy, for example the question of how rush orders are integrated into the transport and production control of the other supply or production program, reveals the emergent characteristics (Dyllick 1982, Röpke 1977) of the considered supply chain (sub)system, which only arise through interaction with other (sub)systems. In contrast to function logistics, the networking of supply chain relationships is therefore not considered ex post, but through the interplay of selection, variation and preservation. Coordination in this sense means **co-evolution** of the "main strands" of logistic-relevant change processes, more precisely, the design of mechanisms for such a joint development. Due to its secondary performance character of supply chain management in industry and trade, particular attention must be paid to the relationship between primary and secondary services (e.g. logistics-oriented product design vs. product-oriented logistics design).

The advantages of an objective hierarchy of supply chains, which also explains its widespread use, can be illustrated by the example of two suppliers of turn signal systems for the automotive industry, **Blinki and Leuchti** (Simon 1978). Both of them produce turn signal systems, each consisting of 1000 individual parts. Leuchti assembles its turn signal systems piece by piece. If he wants to take a break or is disturbed, he has to start all over again. In contrast, Blinki assembles ten parts into a subsystem. In a second step, he constructs another subgroup out of ten of these subsystems. Blinki's turn signal system consists of ten such subgroups. In the worst case, Blinki has nine steps to recover in the event of an interruption. Assuming that a fault occurs in a hundred steps, Leuchti needs about four thousand times more time to build a system. When Blinki works one day, it takes Leuchti 11 years to produce the same quantity. "This time difference shows the difference in the performance of the hierarchical method. It is based on the effect that the existence of stable intermediate forms has on the evolution of complex forms. By shortening the 'stride length' of progress, the probability of finding successful further developments is increased and the extent of failure is limited." (Dyllick 1982, translated) In this sense, hierarchical structures that "grow" slowly over time and are typically only partially modified instead of being completely rebuilt offer the greatest opportunities for the development of digital supply chains.

The objective hierarchization of logistics also finds its expression in concepts such as "modular sourcing" (by Eicke/Femerling 1991), "modular factory" (Wildemann 1994), "fractal factory" (Warnecke 1992), "**modular principle**", "modular packaging", "modularization of supply chains" (Pfohl 1994) and others. It will often also play an important role in digital supply chains. And it explains why borrowed and **incremental variations** are particularly suitable for creating complex relationship in supply chians. It is probably precisely these two forms of variation that take advantage of hierarchization. Incremental variations find their expression in praxi, among others, in the kaizen concept (Imai 1993). The idea of a step-by-step improvement in the sense of kaizen contrasts with revolutionary innovation in the form of an original variation. The realization of borrowed variations can be favored in particular by the instrument of benchmarking (such as Camp 1989, Sander/Brackmann 1995, Walleck/O'Halloran/Leader 1991). In the course of digital supply chains, engineering is supported by suitable assistance systems and the availability of relevant data and their correlations (Vogel-Heuser 2014).

At this point the necessity of a holistic coordination of the selection of development mechanisms becomes clear. For the variation as well as for the selection and preservation there are numerous **mechanisms** available which have to be selected depending on the situation and have to be driven coherently to each other (Figure 2.1).

Figure 2.1 Selected evolution mechanisms of supply chains

Type	Evolution mechanisms		
	Selection	**Retention**	**Variation**
Supply chain capabilities	• Horizontal career • Talent management • Scoring models • Senior hires Recruiting • IT testing	• MBO: Efficiency targets • Learning of solutions • Algorithms • SC academy	• MBO: Market targets • Learning of new capabilities • Crowd- / outsourcing
Supply chain structures	• Field tests/ piloting • Innovation funnel • Employee suggestion scheme • Internal competition	• Performance mgt. • Guidelines / procedures • Certification/ standards • Best practices	• Benchmarking • Kaizen • (Open) innovation • Multi channel • Change management

Triggered by the increasing need for resilience in digital supply chains, the focus is shifting from execution to (meta-)management, from control algorithms to the adaptation of these through **meta-algorithms** and from operative content to normative, such as anchoring the desired competitive advantage in the supply chain philosophy. Due to their complexity-generating "power", the latter are of great importance for integration.

The following case on **innovation management** shows how the evolution mechanisms of the organizational process approach can be implemented quite practically. The core element is the innovation funnel, which produces, evaluates, selects and, if necessary, introduces or preserves new variants. Innovation management is a core component of every digital supply chain:

Project example: Innovation management for supply chains

Initial situation: A company in the automotive supply industry has always had suplly chain management in mind as a competitive factor. The discussion about the possibilities of industry 4.0 motivated the company to also play a leading role in digital supply chains. The company had already implemented a number of smaller use cases. Due to technological developments in the field of cyber-physical applications and the ongoing gains in experience with corresponding operating models, however, the company could not be sure that it would continue to be at the cutting edge of technology in the future.

Objective: The aim of the initiative was to set up a process to keep the company up to date in connection with the industry 4.0 discussion and digital supply chain in particular, to discover new possibilities, to consider promising starting points and to position the company as a leader in the field of supply chain management. The company was aware that such a process has to integrate external sources in a comprehensive way. But also the internal coordination for the selection and evaluation of new ideas under the heading Industry 4.0 should be structured even better.

Approach: The initiative was implemented in three phases: In a first phase, an innovation strategy "Digital Supply Chain" was developed in the cornerstones, i.e. the development needs of supply chain management based on market and customer requirements were coordinated with the technological possibilities of digitalization. In this way, selected innovation focal points could be identified that were considered particularly relevant from the point of view of the company and from which corresponding criteria for the evaluation of new ideas or projects were derived. In the second phase, a process for the identification, evaluation, selection, development and implementation of new ideas was set up, quasi an "innovation funnel". This innovation funnel was characterized by clearly defined milestones, which support the economic efficiency and transparency of the procedure. In the third phase, the ongoing use of the innovation funnel was implemented with the involvement of customers, suppliers and other service providers and responsibility was transferred to the line. The ideas developed for innovations included new products and services as well as innovative processes and business models.

Result and digital relevance: As a result of the initiative, more than 100 ideas were collected each year, more than 20 of which were pursued in the form of feasibility studies on the topic of digital supply chains. The time-to-market, i.e. the period from idea collection to implementation, was more than halved. The so-called hit rate of innovations, i.e. the ratio of evaluated to successfully introduced ideas, was improved tenfold.

Success factors: The following two factors were decisive for the success of the initiative: On the one hand, the definition of the innovation funnel ensured that the ideas that were included for relevant impulses for further development in the sense of a digital supply chain were not limited to the logistics department. Almost all functional areas of the company, suppliers, customers and cooperation partners were integrated into the process of the innovation funnel at a suitable point. And beyond this, a broader community of experts was also involved through innovation competitions. On the other hand, the understanding of innovation was not limited to the technological dimension. Rather, innovations in processes, the operating model, external presentation, etc. were explicitly sought and promoted. Such a broad understanding of innovation allows the participants to think and go completely new ways with a lot of creativity, without being limited by existing structures and habits.

Self-organisation and autopoiesis

The self-organization approach represents the work of a group of scientists who focus their efforts on the phenomenon of self-organization of or in targeted social systems. In contrast to the organizational process approach, the self-organization perspective increasingly turns to the biological foundations of organizational theory. Among others, the **autopoiesis theory** of the neurobiologists Maturana and Varela has a great influence here (Maturana/Varela 1980). However, self-organization research is also influenced by other natural sciences and socio-cultural evolution theory, in particular the concept of the **spontaneous formation of order** by v. Hayek (1969) (Probst 1987). From a business management perspective, the self-organization approach has been developed and developed to this day primarily by two scientific circles, the **St. Gallen School** under Ulrich and the **Munich School** under Kirsch.

The idea of self-organization accentuates the fact that the management's scope for exerting influence is rather limited. The development and order of an organization are largely determined by itself or by its immanent "own life" in the form of self-design and self-direction. In contrast to population ecology, which derives the deterministic moments of the evolution of organizations from their environmental conditions (environmental determinism), this is rather a system immanent lack of freedom (system determinism). This shows a certain similarity to the organizational process approach, which also focuses on internal organizational processes.

However, the phenomenon of self-organization reflects a rather **institutional** phenomenon (Kirsch 1992). This distinguishes it from the functional consideration of the approaches of organizational theory processed so far. Moreover, it is typically not a mechanistic view in the sense that it places the mechanisms of evolution, i.e. selection, variation and preservation, at the centre of its interest. Rather, it concentrates on the self-dynamics in organizations that emerge without such interventions.

Now we have to realize that self-organizing social systems always also include moments of third-party organization, the exact opposite of self-organization, i.e. there is a complementarity between the two phenomena (to Knyphausen 1988). In this respect, organizations will always have an autopoietic and allopoietic character. An "Autopoie-sis-Allopoiesis-Interplay" (Andrew 1981) in this sense is a constitutive characteristic of "living" or existential organizations. Kirsch (1992, translated) suspects: "Perhaps 'evolutionary management' consists (among other things) in creating 'initial conditions' in an third-party-organizing way [...] which are conducive to self-organizing processes, but also influence these processes". And Probst (1987) finally notes characteristics of self-organizing systems, which were already briefly discussed in the second and third parts of this publication.

Figure 2.2 Basic alignments as a function of change

Coordination	Change	
	Stability oriented	Complexity oriented
System building	Specialization	Generalization
System coupling	Third-party organization	Self-organization

Self-organisation in supply chains now means **implementing suitable framework conditions** in the sense of the characteristics just described in order to enable and promote the "self-development" of certain desired results (in more detail Wehberg 1997). This requires a minimum of appropriate external organization of supply chain execution by supply chain management or a meta-level, repsectively. In the course of digital supply chains, for example, this can affect the process of introducing new algorithms for self-management.

It turns out, however, that an increasing self-organization of supply chain management is less a question of the extent of externally imposed rules than of the way in which external interventions take place and follow the requirements of the above characteristics of self-organization (Kieser 1994). In this context, abstract regulations that take effect at the level of the norm are more likely to enable self-organization than concrete specifications that regulate the operative. In this sense, the supply chain manager - as an institution - becomes, so to speak, the "**catalyst**" (Malik/Probst 1981) of the development of the management system for the flow of goods. Similarly, zu Knyphausen (1988) speaks generally of "modulation". Using the example of the introduction of new control algorithms, this can mean that these are developed and applied by the company itself, but their quality is checked and approved by a third party.

For a differentiated understanding of such "catalysis" or modulation, it is advantageous to first consider system-forming and system-coupling tasks separately. The **polarisation** of the system coupling between third-party and self-organisation as well as the system formation between specialisation and generalisation then leads to a conception, as shown in Figure 2.2. Generalization and specialization, unlike self-organization or third-party organization, express a primarily functional viewpoint.

In principle, generalized supply chains can be just as organized by a third party as a specialization may be self-organized. However, it should be noted that generalisation and self-organisation tend to correspond to change-oriented structures and process patterns of supply chain management, whereas specialisation and third-party organisation correspond to stability orientation. Because the high complexity of self-organizing coupling processes probably finds the necessary **degrees of freedom** in generalized management structures, as they were approximated in the course of the third part on the basis of the change-oriented structural discussions for supply chain management (similar to Kirsch 1992). Future-oriented and extroverted supply chain cultures can even be understood as "**implicit coupling patterns**" (von der Oelsnitz 1995) due to their integrating character.

What does guided self-organisation mean in practice? The following case offers an example of the **setting of guard rails**, in the course of which the cooperation of different units of production, delivery and sales is organised comparatively autonomously. Supply chain management already sets the guard rails here today and pays attention to adhering to the given rules of the game along the value chain, but does not control every single order on a detailed level. The case also shows that self-organization and the setting of guard rails is not limited to the use of cyberphysical systems:

Project example: Guard rails for the supply chain organization

Initial situation: A company in the process industry is exposed to a strong commoditization of its products in competition and correspondingly shrinking margins. The organization is strongly functionally divided into the areas of purchasing, production, sales, etc.. An initial analysis of the supply chain potential shows that the lack of coordination along the value creation chain leaves significant savings opportunities untapped.

Objective: In addition to mobilizing innovation activities for the company, supply chain potentials are to be addressed above all by anchoring a corresponding supply chain management function in the organization. In addition to realizing efficiency gains, the functional definition of the responsibilities between the functions has the highest priority from the management's point of view, because one does not want to "disturb" the well-rehearsed organization by introducing a new functionality. In any case a competence wrangling is to be avoided, in the course of which nobody sees itself more responsible for arising errors in the organization. Rather, the new organization is seen as a platform to enable more efficient cooperation along the value chain in the future.

Approach: The new Supply Chain Management function was introduced in the course of a three-stage procedure and the corresponding potentials were addressed. In the first stage, the current situation was baselined and the desired result derived from selected KPIs. This means that a business case was developed for supply chain management (as a function), which was supported by all participants. In stage 2, a draft of the future organizational structure and principles for cooperation were developed. The principles of the organization were based on a supply chain segmentation, i.e. the future rules of the game were developed separately for each supply chain model. The organisational structure was detailed on the basis of corresponding organisational charts, resource estimates and job descriptions. In the third project stage, the new organization was introduced step by step, the employees were trained and the implementation of savings potential was monitored. Among other things, the new responsibilities of Supply Chain Management were appointed, with the project manager assuming the management task of this new function in the line. Last but not least, the organizational principles were integrated as far as possible into the existing IT system world, for example into the PPDS of production and the price calculation of sales.

Result and digital relevance: As a result, the new supply chain management enabled cost savings of 12 percent and inventory reductions of up to 45 percent depending on the product areas and supply chain segments. The transition to an organization that is more closely aligned with the value chain went smoothly thanks to the introduction of rules for cooperation. The self-organizing approach helped maintain entrepreneurship and market focus in the line while improving alignment between line functions. Self-organisation on the basis of organisational principles can be understood as a preliminary stage of self-organisation on the basis of algorithms, i.e. an initial technical concept and the basis for a digital supply chain had been laid.

Success factors: Three factors were decisive for the successful introduction of supply chain management. On the one hand, the decentralized organizational approach helped to secure the "buy in" and acceptance of the established executives. Secondly, the goal-oriented approach from the very beginning was decisive in ensuring that the project did not run the risk of being (mis)understood as a pure organizational project. And thirdly, cross-functional cooperation made it possible to realize significant improvement potential because it was not satisfied with island solutions. The relevance and extent of these potentials also supported the acceptance of the project.

Cybernetics

The cybernetic approach comprises the description, explanation and design of the development of organisations from the perspective of control loop theory. In addition to dealing with processes that maintain equilibrium (first-order cybernetics), it also and above all deals with **imbalances** in the sense of second-order cybernetics. With regard to the type of regulation, this means that the cybernetic approach deals not only with negative, but primarily with positive feedback in regulation systems (Sprüngli 1981). The former stabilise a desired state in the long term by preventing deviations from a certain controlled variable. They are doing so by damping them to a certain extent through negative feedback, and in a way by punishing them. Numerous structures, no matter whether in economy, society, technology etc., cannot be kept constant for a long time due to their openness and the complexity of their environment. Especially in the management of organizations, not only "punishment and damping", but also "confirmation and reward" of deviations play an important role. The latter, the positive feedback, characterizes the destabilization of systems in the form of increasing feedback loops (similar to Sabathil 1993). They lead to increasing system complexity.

Positive and negative feedback in the development context are now typically in a complementary relationship to each other, stabilizing and destabilizing moments of organizational structures always alternate. Such an interplay of feedback mechanisms can also be documented by the concept of the **equilibrium of flow** originally coined by v. Bertalanffy (1953), a phenomenon to which the cybernetic approach pays special attention. Systems that can adapt their control mechanisms in this way are "adaptive control systems". A distinction must be made between "ultra-stable" and "multistable" control loops (especially Ashby 1974, Beer 1966, 1970, Krieg 1971, Pask 1972 and especially for the application of theoretical considerations of control loops in supply chain management Wehberg 1997).

One of the probably most significant design principles of the cybernetic approach is the **law of the required variety** by Ashby (1956), "only variety can destroy variety". According to this, the minimum variety of a degree of target achievement of a considered supply chain presents itself as the quotient of the variety d of an influencing environment and the variety r, which the considered supply chain can oppose to the environmental system, provided that for the considered supply chain to achieve its targets an adjustment is necessary with any changes of the environment: $o \geq d/r$. The "variety" can be understood as a measure for the concrete characteristic of the system complexity. To this extent, it may also be translated with the term "change" used in this publication and borrowed from the St. Gallen Management Concept. Unlike the concept of change, however, "variety" expresses a direct connection with the theoretical foundations of control loops.

The Variety Law can be applied both in terms of recording and handling the complexity of the supply chain. The starting point for the corresponding handling of supply chain organizations, also known as "Variety Engineering", is now the establishment of adequate feedback mechanisms or control systems. (general Probst 1981, Schwaninger 1994). They can basically be transferred to the supply chain and are particularly interesting in connection with digital supply chains because they provide a good basis for the development of algorithms or meta-algorithms, respectively. In particular, the digital twin of a supply chain is essentially a control loop.

However, it is not only the number of supply chain-relevant variables themselves (quantitative dimension) that determines the manageability or controllability of the overall system. Rather, it also depends on the concrete content of the change possibilities (qualitative dimension). The respective forms of appearance of the supply chain and the surrounding system must fit together in terms of content. It should also be noted that absolute control of a supply chain is impossible in the majority of cases because the variety of the surrounding system is too great (in general Luhmann 1990). It can also be economically viable to limit the variety of a supply chain (differently e.g. Kieser 1995). Here, the (opportunity) costs of setting up a variety are contrasted with the gains in resilience (Wehberg 1994). The latter efficiency considerations then stand in the way of the highest possible effectiveness of supply chains. In order to solve this trade-off, therefore, no minimum, but rather an appropriate variety gap and a (probably) satisfactory level of effectiveness should be striven for. At the same time, the digital supply chain opens up the possibility of realizing such a satisfactory fit at a higher (effectiveness) level.

2.2 Integration of perspectives and key design principles

Most of the above design perspectives are not related to each other in any way. Rather, they usually complement each other. For example, it may be useful to design the (meta-) evolution of development mechanisms (organizational process approach) in a largely self-organizing way (self-organization approach). This can then generate the supply chain variety that is needed in turbulent environments to absorb the external variety (cybernetic approach).

The dichotomization of supply chain structures in change and stability orientation carried out in the course of this publication is in principle compatible with cybernetics, but also with the further approaches of holistic evolutionary organizational theory. There are, for example, parallels between the measures of variety and change. In this respect, the previous theoretical foundations can be incorporated into the digital supply chain through the frame of reference on which this work is based. Ultimately it is always a question of **profiling the supply chain between stability and change orientation** or of creating the "right" degree of complexity according to the situation.

Umbrella for key design principles

In this sense, Figure 2.3 summarizes the common directions of the different approaches of holistic-evolutionary organizational theory, as well as other concepts.

Of course, this is not a complete conceptual consolidation of the different evolutionary approaches of management, but rather the classification into a frame of reference, which does not hide their differences and diverging fields of application. The suggested frame of reference rather tries to emphasize the common denominator of relevant perspectives. The attempt to integrate the various approaches of holistic-evolutionary organizational theory would probably also be premature, as they are still predominantly in the early stages of their development. It is precisely the multi-conceptual perspective of the frame of reference that makes it possible to convey a deeper understanding of the concept of a resilient supply chain management. The reference framework of the digital supply chain presented here thus represents a kind of **umbrella concept**. It is open for the integration of further concepts.

Figure 2.3 Common directions of selected theoretical concepts

	Complexity decrease	Complexity increase
Ashby, 1956	Low variety	Large variety
Bleicher, 1991	Stability orientation	Change orientation
Campbell, 1975	Preservation, propagation	Variation
Hannan, Freeman, 1977	Selection, retention	Variation
Von Hayek, 1972	Competitive selection, multiplication	Variants
Kirsch, 1992	Allopoiesis	Autopoiesis
Probst, 1987	Third-party organization	Self-organization
Popper, 1973	Correction of errors	Trial
Röpke, 1977	Selection, retention	Variation
Wehberg, 1994	Third-party org., specialization	Self-organization, generalization

Against the background of such multiconceptual structure of the frame of reference, three essential basic interrelations can be summarized, which concern the evolution of the supply chain:

- What does the coordination principle of self-organisation mean for the digital supply chain, specifically?

- What is the connection between change and fitness of the supply chain and what is the effect of digitisation?
- What are fundamental behavioural strategies for the evolution of digital supply chains in the course of a resilient understanding?

Design principles of self-organisation

Let`s start with the first question, what does the coordination principle of self-organization specifically mean for the digital supply chain? As already mentioned, self-organization has four characteristics, which is recursion, autonomy, redundancy and self-reference. For the digital supply chain, this translates into design principles for digital supply chains, which suggest (Figure 2.4):

- The **steering** has to be consistent on different levels (in line with actual supply chain models). The **modularization** across hierarchy and **standardization** across sites are key for digital supply chains. All together, they support the recursion of a supply chain, which means certain characteristics are similar on different factual hierarchy levels.
- Responsibilities need to be **end-to-end** (rather than an organization for example for Scor-functions with split-responsibilities). **Online-transparency,** an **enforced alignment** (so that there is one aligned approach to coordination between functions and escalation mechanisms, accordingly) as well as **no management intervention** are required. All this together enables autonomy. The supply chain manages or develops itself and seeks its own way for this, without there being a central unit for it. Controlling and controlled unit are then one.
- Relevant information have to be **shared**, openly. The sharing needs to be on a **real-time** basis and with means of **one data lake** as one source of truth. This makes sure that those units that have influence, each of which has (most or best) information, which means redundancy.
- Last not least, digital supply chains have to **continuously improve** with means of **dynamic forecasting** and **machine learning** technology amongst others. This is to to make sure the behaviour always reacts back to it and these feedbacks in a way form the basis for further behaviour in terms of self-reference.

Considering these design principles, digital supply chains can absorb a huge amount of change because they can create significant resilience themselves without becoming chaotic or unreasonably complex. Needless to say, aforementioned principles represent some key requirements from a self-organization viewpoint. They are not necessarily complete. Today, these principles are not being considered in a huge number of supply chain organisations if not the majority of them.

Figure 2.4 Selected design principles for digital supply chains

Recursion	• Consistency of steering
	• Modularization across hierarchy
	• Standardization across sites
Autonomy	• End-to-end responsibility
	• >95 percent online
	• Enforced alignment
	• No management intervention
Redundancy	• Real-time transparency
	• Sharing
	• One data lake
Self-reference	• Dynamic forecasting
	• Continuous improvement
	• Machine learning

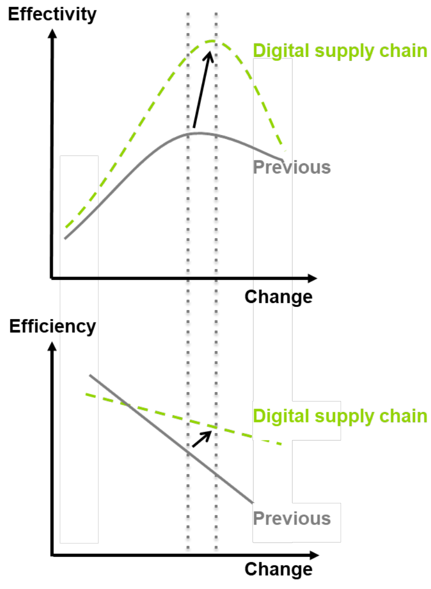
Supply chain fitness

What is the ideal basic relationship, then, between the change in the supply chain on the one hand and its effectiveness and efficiency on the other? It should be noted that with increasing changes in a supply chain, its efficiency regularly decreases (see Figure 2.5). Above all, highly stabilized structures lead to **specialization gains** and economies of scale with regard to the cost structure. In contrast, change usually causes complexity costs and is therefore (ceteris paribus) associated with efficiency losses.

On the other hand, the effectiveness increases, against the background of the law of variety, with increasing changes in the supply chain. However, this behavioural relationship cannot be applied in every case with extremely high complexity. In this respect, the Variety Law can have a limited validity with regard to supply chains. With very high uncertainty and frequency as well as correspondingly low compatibility, the principle of the **ecological niche width** can presumably guarantee a higher effectiveness (deepening Wehberg 1997).

Figuratively speaking, the position of the effectiveness and efficiency functions cannot be influenced in any way. By considering new potentials, such as new technologies like cyberphysical systems, it is possible to proactively shape the results of a supply chain. Thus, the digital supply chain improves the efficiency behaviour in the case of medium to high changes. With low changes, the **complexity costs** of the digital supply chain are at the expense of efficiency, because the **resilience** of the digital supply chain remains untapped. And the effectiveness function of the digital supply chain also offers advantages if the desired supply chain goals, such as delivery flexibility and reliability, can be better achieved with high changes.

Figure 2.5 Relationship between the change, effectiveness and efficiency of a digital supply chain (illustrative)



The **fitness of the supply chain** now results from the overall view of the various efficiency and effectiveness functions of its individual subsystems. As a rule, as the supply chain under consideration changes, fitness initially increases and then decreases again at a critical point. The low fitness of supply chains with a maximum or minimum degree of complexity stems from the consideration that extremes, here change, are in the majority of cases 'deadly' for a system, i.e. it can no longer perform its function (generally Probst 1987). Apart from the extremes of a minimum and maximum change considered here, the exact position of the fitness function is by no means fixed. Rather, it can be assumed that there are different patterns with regard to the effectiveness of the supply chain, each describing different typical behaviors of a subsystem of the supply chain. The same applies to their efficiency.

The above static perspective must now be supplemented by a dynamic view of the typically oscillating changes in supply chains (Göpfert/Wehberg 1996). For example, adaptations to a change in the supply chain environment, as well as self-initiated innovations, require a sufficient change orientation if the effectiveness of a supply chain is to be further guaranteed. Change-oriented structures are useful, for example, in the transition from the market development phase to the diversification phase, but also in numerous other upheaval and transition phases for the supply chain. If supply chain management fails to anticipate changes and initiate suitable measures, such a misfit can lead to "crises" that threaten the existence of the company and leave no time for integrated and planned solutions. The rigid connection to suppliers and the wrong location of a large warehouse can be exemplary triggers of crisis situations.

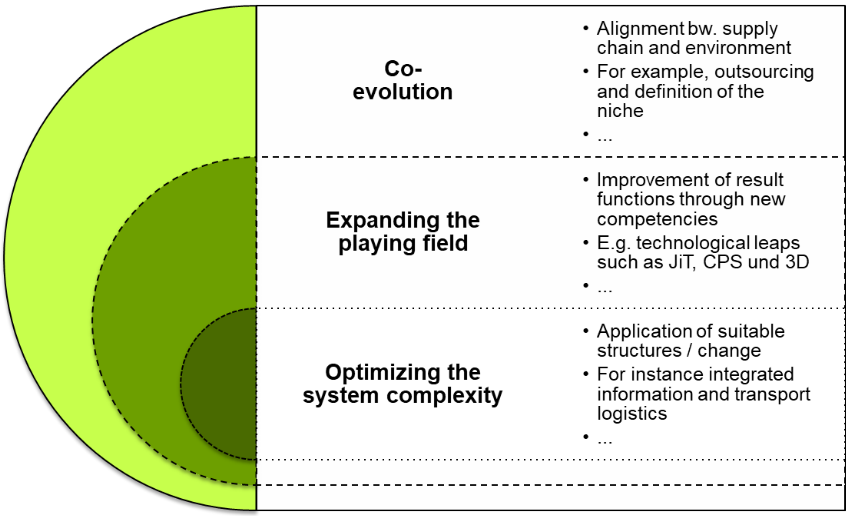
Pfohl (1994, translated) speaks similarly of **crisis-oriented supply chain management**: "In crisis-oriented logistics management, the analysis and solution of logistics problems is not yet carried out continuously on the basis of the logistics concept. [...] Logistics problems are not actively uncovered in time by logistics management, but are merely reacted to obvious symptoms that show the existence of bottlenecks (weak points, disruptions). Such symptoms are, for example, eye-catching frequent restacking of pallets, long queues of lorries at the ramps of a warehouse during the delivery of goods, or many cross journeys between delivery warehouses.". The prerequisite for avoiding or overcoming such crises is consequently a minimum degree of change-oriented orientation of logistics management.

However, as already mentioned, a change orientation has to be bought regularly through losses in efficiency (adjustment costs). Once the "right" structures to ensure effectiveness have been established, it is therefore a matter of increasing the economic efficiency of the supply chain again through rather stability-oriented measures. As a rule, what has been newly learned must first be deepened by supply chain management before it can be used efficiently. This also applies in principle to self-organizing cyberphysical systems of digital supply chains. More stability-oriented orders can prove advantageous, for example, in the transition from the pioneer to the market development phase. The spectrum in which such an interplay between change and stability orientation takes place - which is reminiscent of the phenomenon of the flow equilibrium - defines the adjustment area of supply chain management.

Strategies of supply chain evolution

What are fundamental behavioural strategies for the digital supply chain in the course of a resilient understanding? In order to minimize the dilemma between efficiency on the one hand and effectiveness on the other, there are three basic approaches to supply chain evolution, which are briefly explained below (Figure 2.5):

Figure 2.6 Evolution strategies of digital supply chains



First, it can be attempted to exert a corresponding influence on the development of the environment in the sense of **co-evolution** in order, for example, to stabilise supply-chain relevant parameters. Among other things, the outsourcing of logistics services can contribute to the stabilization of the environment if the complexity of the relevant influencing variables for the supply chain under consideration is reduced in this way. The principle of ecological niche-wide support offers assistance in defining the suitable niche. True pioneers will also be tempted to set dynamic accents in competition and new market standards through appropriate innovative behaviour in order to realise corresponding first-to-market profits in the medium term. The strategy of co-evolution should therefore be interpreted dynamically. It does not exclude the evolution strategies described in the following, but is to be understood rather spreading.

In addition to attempting to exert a favorable influence on the supply chain environment, it can also be promising to influence the effectiveness and efficiency functions of supply chains yourself. For example, it can be targeted so that the degree of efficiency conflicts as little as possible with a major change in the supply chain. It is about **expanding the playing field** for supply chain management, specifically about improving its functional relationships between change and its results by introducing new supply chain competencies such as digitalization. The possible evolution mechanisms for the development of corresponding capabilities have been explained above. In this way, new standards are set for the effectiveness and efficiency of the supply chain of the company under consideration, but possibly also absolutely in the form of a new state of the art. Relevant starting points offer in particular technological leaps such as the use of flexible manufacturing technologies, DOMRP, Just-in-Time and Postponement. It has also already been explained above why a digital supply chain is suitable for expanding the playing field of supply chain management in this sense, i.e. offering new options for action in the form of the development of networks. It will not always be possible to differentiate between the adaptation of the change in supply chains and an adaptation of its efficiency or effectiveness function, because the latter includes new possibilities for the former.

Thirdly, if one starts from given functions, it is important to apply structural patterns that bring about a far-reaching harmonisation of supply chain objectives, which means **optimizing the system complexity**. The possible evolutionary mechanisms for the development of corresponding supply chain structures have been explained above. A selection of essential patterns was presented with the change profiles in the course of the third part. The in-depth breakdown of change profiles ensures the application relevance that is so important for supply chain practitioners. In this way, evolutionary theoretical statements are "broken down" from their high level of abstraction to the specific problem area of a supply chain. For this reason, the next steps typically relevant for the supply chain practitioner, i.e. the question of how effective supply chain structures are planned and implemented in practice, will also be addressed in the following. In doing so, it builds on the resilient understanding of supply chain management as well as on the reference framework of digital supply chains presented here.

3 Next steps for the digital supply chain

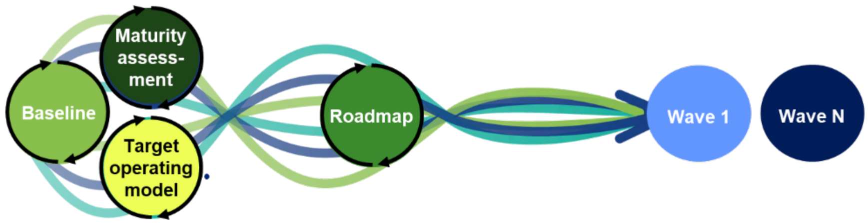
3.1 Overall approach to digitalization of the supply chain

How to get started? All the before mentioned is only meaningful if it is used for making digital supply chains happen. So, the question is how to do it, practically. In reality, many discussions on digital supply chains focus to leverage new technologies. However, while better understanding the current situation and starting point of the respective company, in many cases one finds out that digitalization is not necessary the next step. This is just because the repsctive supply chain is not really mature enough and well prepared to face digitalization. In other words, the company is pursuing a supply chain understanding other than a resilient one. Basics need to get fixed first in terms of a process-oriented or demand-driven understanding. On the other hand, a subsequent approach that first takes care for basics takes to much time and does not support a proper time-to-market of digitalization concepts. This is especially critical because digital supply chains are key facilitator for new business models and digital offerings. The right timing often decides who will takes the system lead in certain markets, e.g. as platform operator. A typical approach, therefore, needs to fix the basics while digitalizing the supply chain in parallel.

Of course, for introducing a digital supply chain based on a resilient understanding the approach itself in a way needs to be **agile**. The proposed steps shown in Figure 3.1 are therefore not to be interpreted in a subsequent manner, however, they are based on sprints and consider the design thinking methodology. The firts three steps of the approach, the baselining, maturity assessment and target operating model definition, thus follow this kind of methodology for exactly that reason.

Moreover, introducing a digital supply chain is never a one-off excercise but a continous effort. At the same time, it is vale-adding to schedule a comprehensive transformation journey and „slice the elephant“ with means of a realistic implementation roadmap and waves, accordingly. In order to succeed, typically, one has to think big, start small and scale fast.

Figure 3.1 Typical approach for supply chain digitalization



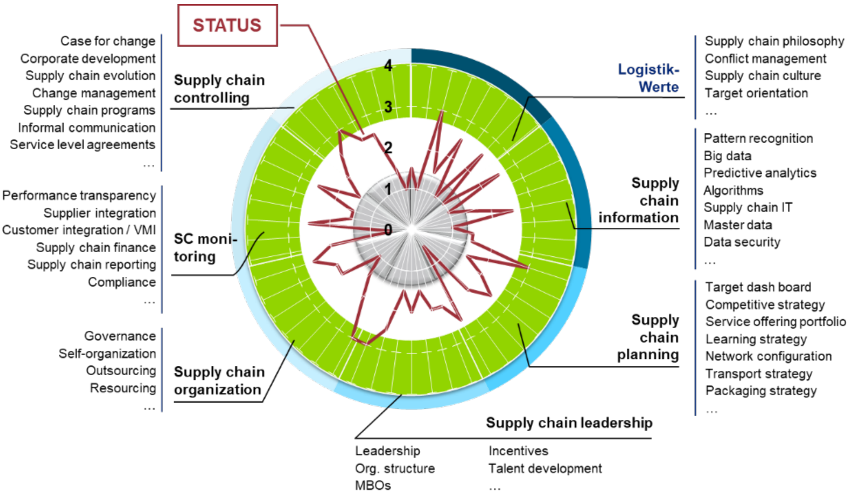
3.2 Baselining and assessing maturity

Anyone who wants to develop supply chains in the direction of digitalization must first understand the development to date, the status and the key factors influencing future development. As a rule, a series of **fundamental analyses** in the sense of a "baselining" of supply chain (management) structures are available to support the answering of the aforementioned questions, e.g.:

- Evaluation of relevant trends using trend sonar,
- Review of corporate strategy and desired competitive advantage,
- Environmental analyses including supplier and competition surveys,
- Customer and employee satisfaction analyses,
- Survey of service levels for internal and external customers,
- Process maps to illustrate the value creation structure,
- Assessing the maturity of supply chain (management) processes,
- Evaluating supply chain performance with means of process mining,
- Understanding the cultural readiness to change and digitalization,
- Resource surveys (costs, employees) on the basis of a process framework and organizational structure.

Often, a lot of information and tools are already available in the company, so that a comprehensive survey of all the aforementioned aspects can be dispensed with. When recording the **maturity** level of a supply chain, the focus is on the ability to cope with complexity or to generate complexity itself in an orderly manner. Figure 3.1 shows an overview of a corresponding methodology.

Figure 3.2 Maturity assessment for digital supply chains



3.3 Defining the target operating model

When deriving the target state in the direction of digital supply chains, the same dimensions of supply chain management can be used as for maturity measurement. The desired operating model (target operating model) of the supply chain is to be defined holistically in the form of an end-to-end view, including supply chain information, planning, personnel management, organization, monitoring and control(ling).

In terms of supply chain evolution, the establishment of responsibilities for the supply chain of a company is often a first step in development. The way supply chain management is anchored within the organization typically says a lot about the appreciation of it as well as the supply chain governance. Once a **supply chain governance** is installed, this goes hand in hand with the desire to create more transparency about supply chain processes. **Transparency**, for example about the actual costs of supply chains, often offers a kind of "aha" effect about their actual significance. In many companies, supply chain costs are limited to the transport department, for example, and are not seen as process-related. Once the importance of supply chain management has been understood, this is the basis for tackling improvements and systematically planning them. The logic of different **supply chain modles** is being understood. The focal points of such improvements are to be worked out sector- and company-individually. A solid supply chain planning is then the basis to understand its implementation. For this reason, many companies focus on the control system. A comprehensive establishment of the digital supply chain requires not least a suitable development of both the personnel management and values, respectively. The latter are indispensable for the sustainable anchoring of a corresponding control philosophy in the minds of the employees.

Figure 3.3 Example patterns of typical supply chains

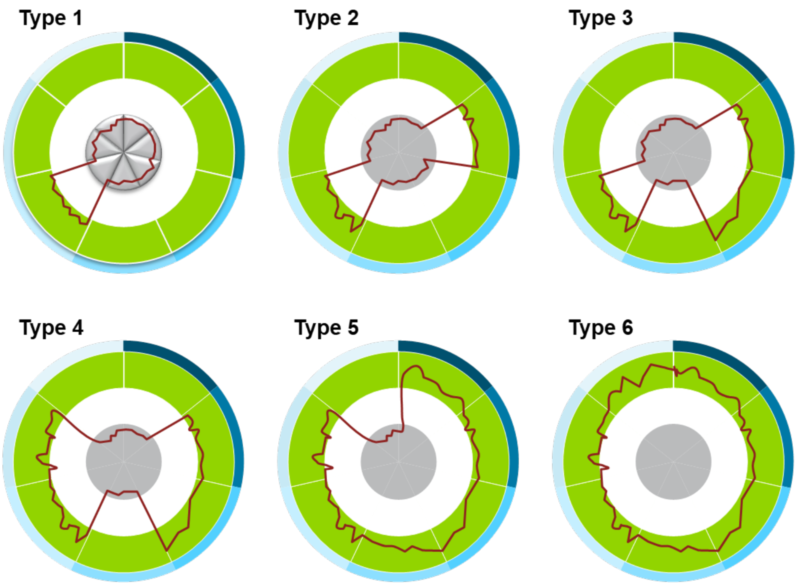
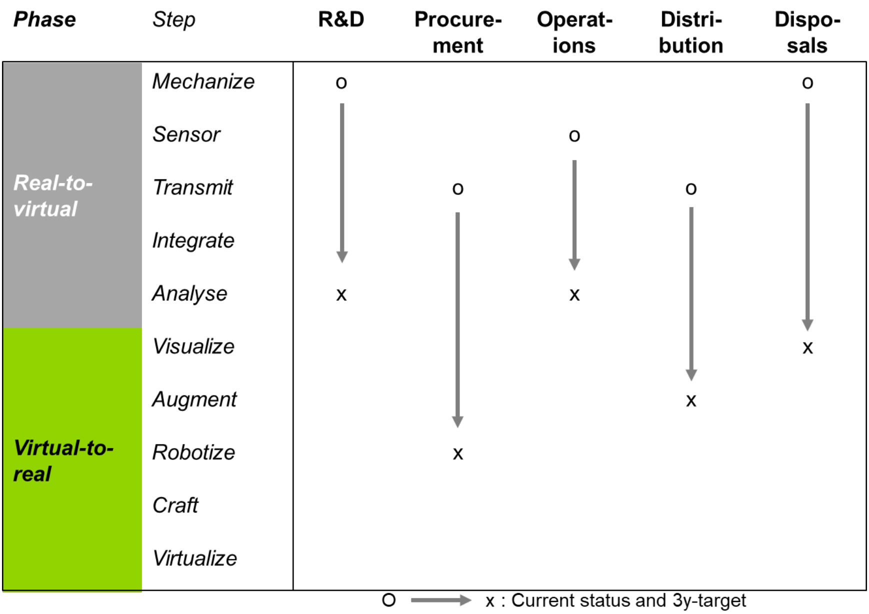


Figure 3.2 shows such typical supply chain structures and evolution stages using exemplary patterns. Of course, it may also be expedient for the company under consideration to adapt the sequence of the addressed supply chain subsystems or to bring the entire supply chain management to a medium degree of maturity

before it takes the idea of digitalization into account.

In order to drive supply chain evolution and improvements associated, it is vital to have a proper approach to the operational supply chain corrdination in place. As mentioned earlier, the digital twin of the supply chain is facilitating this kind of optimization loop with means of 10 key milestones. To target and measure the progress from one milestone to another, an assessment as well as target definition of the digital twin helps to keep transparency and **track for the build-up of the digital twin** on a milestone-specific basis. Figure 3.3 shows a respective monitoring chart with respect to the end-toend supply chain as an example. This is typically a key input for tracking a business case and thus providing evidence for the commercial viability of the transformation towards a digital supply chain. In this context it is important to understand that in not just a few cases the baseline data for buidling a business case is poor. In this case it is important to double-check the baseline-performance at a later stage with means of digital-twin measurements, and to update wehere needed. Otherwise, it can happen than improvements seem to be even negative just because actual figures are compared against wrong baseline data.

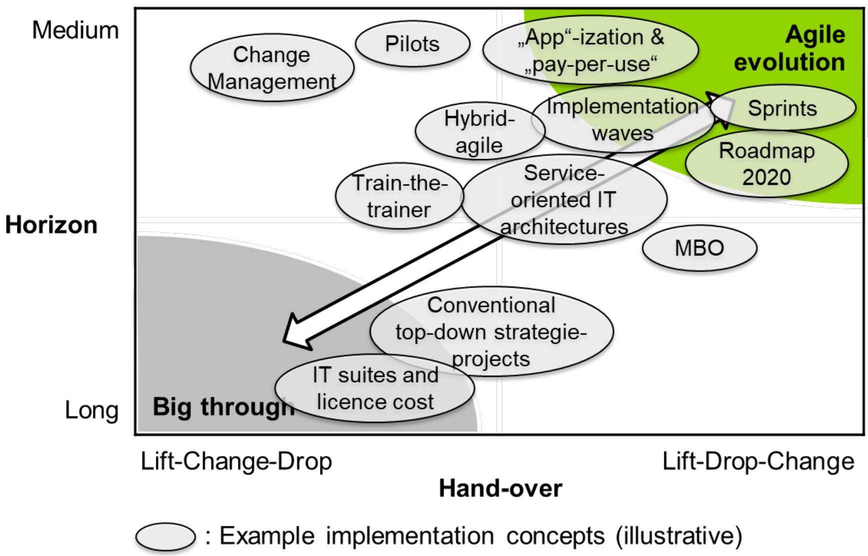
Figure 3.4 Assessment of the digital twin of a supply chain (example)



3.4 Planning the implementation roadmap

As you make your bed, so you sleep. Implementation planning is therefore a step in supply chain development that should not be underestimated. Many practitioners run comparatively unconsciously into an adventure if they do not systematically consider the desired target status nor the prerequisites, implementation steps, resources and employees necessary for its realization. Due to a planning of the "big throw", many companies also tend to define the implementation steps too big, too confusing and too ambitious. In both cases, there is a risk of a nasty awakening. Often the concept is then seen as the cause of failure, although it was not the "what" but the "how at the what". An agile implementation in clear steps is more promising here, but does not mean that an overall big picture would not be necessary, where the company would like to go in the result (Figure 3.4).

Figure 3.5 Implementation strategies



Last but not least, a fundamental decision about the implementation strategy has to be made in the course of the implementation planning: If the new **supply chain responsibilities** are to be established first in order to be able to take them into account for implementation ("Lift-Drop-Change") or if the improvements from a project are to be addressed in order to then hand them over to the new responsibilities ("Lift-Change-Drop"). In many cases the "lift-drop-change" has proven itself in practice, because the implementation is directly driven by those responsible at a later stage and therefore a different level of motivation and sense of responsibility is supported. One could also say that those who have to spoon out the soup will also ensure that it tastes good. But there may also be reasons for an adapted approach, for example in the sense of a "lift-change drop". If the supply chain capabilities are missing, for example, it can be reasonable to train future responsibles during the transformation and install the new roles based on a proven project path. A change-lift drop, on the other hand, is seldom promising.

The following case is intended to serve as an example for the temporal structuring of the implementation of the target image on the basis of an implementation timetable:

Project example: Supply chain roadmap

Initial situation: A company in the manufacturing industry segment faced intense competition both in terms of its product range and external growth. Due to the pressure on margins, the company was looking for potential savings in all directions. At the same time, the possibilities of digitization were to be examined, because growth and innovation potential was suspected here. Due to the pronounced product and technology focus in the past, corresponding potentials were expected above all in the area of the supply chain, in particular in the redesign of the value-addeding structure. Due to the neglect of supply chain issues in the past, the range of possibilities in this area was particularly wide. At the same time, the decision-makers and opinion leaders in the company disagreed as to where best to start and in what order the topics should be dealt with.

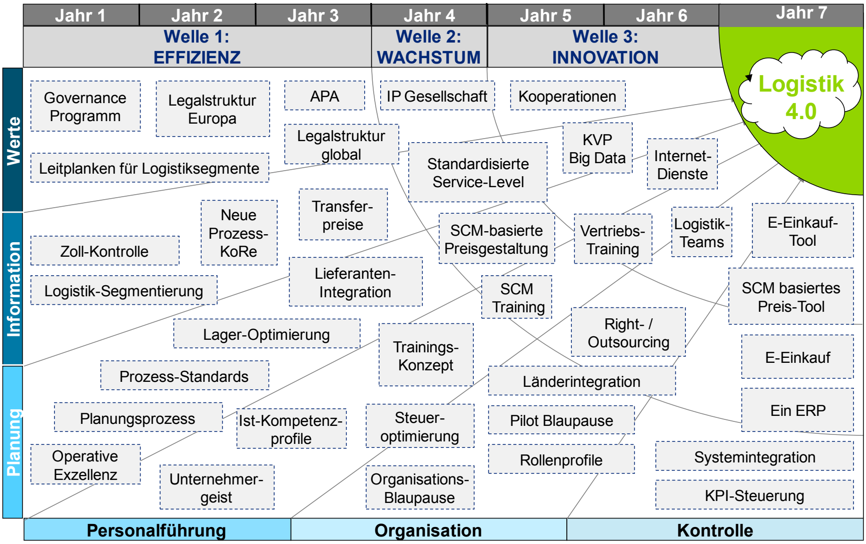
Objective: Against this background, the company management initiated a preliminary project to order, prioritise and project the possibilities for improvement in the supply chain area. The goal was a well thought-out roadmap (Figure 3.5), supported by everyone, that would chart the path of supply chain development over the coming years. At the same time, a step-by-step approach should ensure that each step is self-contained and offers sufficient benefits - also seen in isolation.

Approach: The procedure for drafting the roadmap consisted of three steps. First, the current state was to be reviewed, which already existed in many respects but was incomplete. The approach was pragmatic because the company did not see any actual benefit in much analysis activity. Rather, they wanted to complete the required data as required. Secondly, potential improvements were assessed in the form of rough first business cases. Here, too, the 80:20 principle was applied pragmatically. In order to ensure that no significant opportunities for improvement were forgotten, the company put this exercise on a broad basis, attached great importance to the involvement of those affected at all levels and also initiated comparisons with other companies. The possibilities for improvement were arranged according to the management areas of the supply chain, for example the information system, planning, organization, etc. The improvement possibilities were also evaluated. Thirdly, each business case was concretized with regard to responsibilities, resource requirements, exact milestones, etc. and an overall roadmap was drawn up by consolidating the various milestones. In addition to the targeted interim results, the milestone planning also included communication and the necessary resources. The roadmap was divided into three waves: Wave 1 stood for efficiency improvements and a state-of-the-art organization, wave 2 for growth and concentration on core competencies through outsourcing and wave 3 for innovation and new services.

Result and digital relevance: The roadmap summarized more than 35 projects with over 400 milestones over a period of seven years. Thus, the company's journey towards the introduction of a progressive supply chain function was fully structured. Due to the existence of the roadmap, the company's journey was well thought out, so to speak, in every stopover and to the end, even before the start of the journey. The sum of the business cases resulted in a net present value in the higher three-digit million range. Efficiency (inventory, etc.), growth (pricing, etc.) and innovation topics (new services, etc.) were equally taken into account.

Success factors: The success of the roadmap was demonstrated above all by the successful implementation of its milestones. Three success factors were decisive for the quality of the roadmap development: participation, competence and evolution. Participation meant bringing all important decision-makers and those operationally affected on board. Without their expertise, feasibility, comprehensiveness and acceptance would have been in jeopardy. Competence means defining the roadmap within the framework of the company's capabilities and available capacity. Ambitious but unrealistic project plans are of no use to anyone. Rather, it is the reliability of the roadmap that is important, especially when considering the situation over several years, in order not to get out of hand right from the start. Evolution therefore means structuring the roadmap into smaller, controllable steps with corresponding intermediate successes that do not lose momentum over the years of implementation.

Figure 3.6 Example supply chain roadmap



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Part 5: Over and beyond digital supply chains

This book offers an initial basis for digital supply chains, which includes both practical experience as well as a theoretical-conceptional fundament. The problem of managing complexity has so far only been dealt with rudimentarily in the supply chain literature.

Writing a final publication on integration, comprehensiveness and complexity management in logistics is probably a contradiction in terms. From a systemic point of view, there can be no "big last litter". It should therefore be pointed out that the frame of reference of this publication is open in principle. The latter is to be understood as a "first step" towards a theoretical foundation of digital supply chains and ist resilient understanding. And even against the background that organizational-theoretical evolutionary research has "only" tried to establish itself for about forty years, it is not surprising that the need for research in this area, measured by its significance for supply chains as well as for management in general, is comparatively great. Numerous questions were raised here. However, a final answer could - of course – not be offered. In particular, the following continuing research tasks can be highlighted:

- The admissibility of transferring statements from basic sciences (such as biology, neurology, etc.) to supply chains needs to be examined in greater depth.
- The evolutionary mechanisms of supply chains and their development need to be explored more extensively.
- Typical behaviour patterns need to be developed in a more differentiated way.
- The social and technological dimensions of supply chain development in particular need to be further conceptualised.
- The complexity management of supply chains should be further shaped in such a way that tool-supported work is expanded.

But also the empirical testing of model hypotheses should be promoted. Both together, the further theoretical-conceptual as well as empirical foundation, promise an essential expansion of the understanding of the digital supply chains and ist resilience in particular.

At the end of the day, all the answers to be worked out will have to prove themselves in the light of practice. Without offering such added value in practice, it is merely a scientific activity as an end in itself. In this respect, supply chain management is called upon to prioritise the above questions from a practical perspective. In addition, practical considerations for the respective company come in the form of numerous W questions regarding digital supply chains, for example:

- What are the customer benefits and values of digital supply chains in the various segments?
- What are practical learnings that have to be incorporated in order to sharpen the framework?
- What kind of economic viability does the use of cyberphysical systems typically offer?
- What initial investments are required to set up a digital supply chain?
- What do the (meta-) algorithms for digital supply chains look like?
- Which way can digital supply chain solutions be implemented holistically?
- When is an organization ready for the introduction of a digital supply chain?
- What implementation risks must be managed with regard to digital supply chains?
- What are typical success factors for the implementation of digital supply chains?
- Which is the best way for digital supply chains to be organizationally anchored in the company?
- What kind of digital supply chain competencies are required?
- What does a digital supply chain mean for the outsourcing strategy?
- What more can we learn from other application examples?
- Which is the best way to answer questions of data security satisfactorily?

The practical desire for suitable support to answer the relevant questions is obvious. Such supply chain will certainly play its role in the course of the fourth industrial revolution. As I suggest, we all can very much look forward to our next steps and shared learnings in our joint digitalization journey.

The ten biggest errors as to digital supply chains

Sometimes the best way to describe something is to say what it isn't. In this sense, I would like to conclude by summarizing in a pointed way the ten biggest mistakes regarding digital supply chains, which I encounter conveniently:

Error No. 1: Digital supply chains will be important, but will not revolutionize our lives.

Wrong, digitalization offers the potential to build supply chains completely differently and to develop new business models. The Internet of Things is revolutionizing logistics, among other things.

Error No. 2: Digital supply chais help to reduce complexity.

Wrong, complexity can only be handled with complexity. The answer to increasing environmental and market requirements (customer expectations, regulations, scarcity of resources, etc.) is therefore resilience and flexibility.

Error No. 3: Digital supply chains mean maximum self-organization.

Wrong, the delegation of responsibility and decentralisation of decisions do not mean the complete abandonment of design and development possibilities. It depends on the right scope and degree of self-organisation as well as the right guard rails.

Error No. 4: Digital supply chains are an efficiency engine, but not a growth engine.

Wrong, the use of the Internet of Services in the field of supply chains offers potential for many new services and business ideas. This offers growth opportunities for companies and regions.

Mistake No. 5: Digital supply chains are what I do by doing a bit of cyberphysics.

Wrong, digital supply chains are more than a new technology. Cyberphysical systems make many things possible. However, digital supply chains can be implemented as a holistic management concept for individual companies. It affects all areas of management.

Error No. 6: Digital supply chains mean finding the right algorithm for forecasting.

Wrong, the relevant procedures typically offer a whole series of algorithms for a specific question. The all-healing algorithm does not exist. And not everything can be forecasted.

Error No. 7: Digital supply chains mean collecting as much data as possible.

Wrong. It is not about a comprehensive consideration of as much data as possible, but about the integration of the relevant sources. Relevant are those data that serve to achieve the supply chain goals such as forecast accuracy or resilience.

Error No. 8: Digital supply chains require Big Data and CPS competence but no supply chain management knowledge.

Wrong. The analysis and management of complex supply chains require not only the necessary IT and analytical competence, but also an understanding of logistics, flows and value chains, because this is precisely where judgement and business knowledge are required.

Error No. 9: Digital supply chains are already covered by the current Industry 4.0 Initiative.

Wrong. The degree of maturity of supply chains in industry is very different. Quite a few companies first have to implement minimum standards in the field of supply chain management before they can devote themselves sensibly to the subject of industry 4.0. An industry 4.0 without sufficient supply chains does not work.

Error No. 10: Digital supply chains are not a matter for the CXO, but a task for the logistics department.

Wrong. Digitization belongs on every board agenda. The design of the company's value creation structure and business model is strategic and critical of competition.