McKinsey&Company

Supply Chain 4.0 – the next-generation digital supply chain

Supply Chain Management June 2016

Supply Chain 4.0 – the next-generation digital supply chain

Knut Alicke, Jürgen Rachor, Andreas Seyfert

"Supply Chain 4.0 – the application of the Internet of Things, the use of advanced robotics, and the application of advanced analytics of big data in supply chain management: place sensors in everything, create networks everywhere, automate anything, and analyze everything to significantly improve performance and customer satisfaction"

Over the last thirty years, logistics has undergone a tremendous change: from a purely operational function that reported to sales or manufacturing and focused on ensuring the supply of production lines and the delivery to customers, to an independent supply chain management function that in some companies is already being led by a CSO – the Chief Supply Chain Officer. The focus of the supply chain management function has shifted to advanced planning processes, such as analytical demand planning or integrated S&OP, which have become established business processes in many companies, while operational logistics has often been outsourced to third-party LSPs. The supply chain function ensures integrated operations from customers to suppliers.

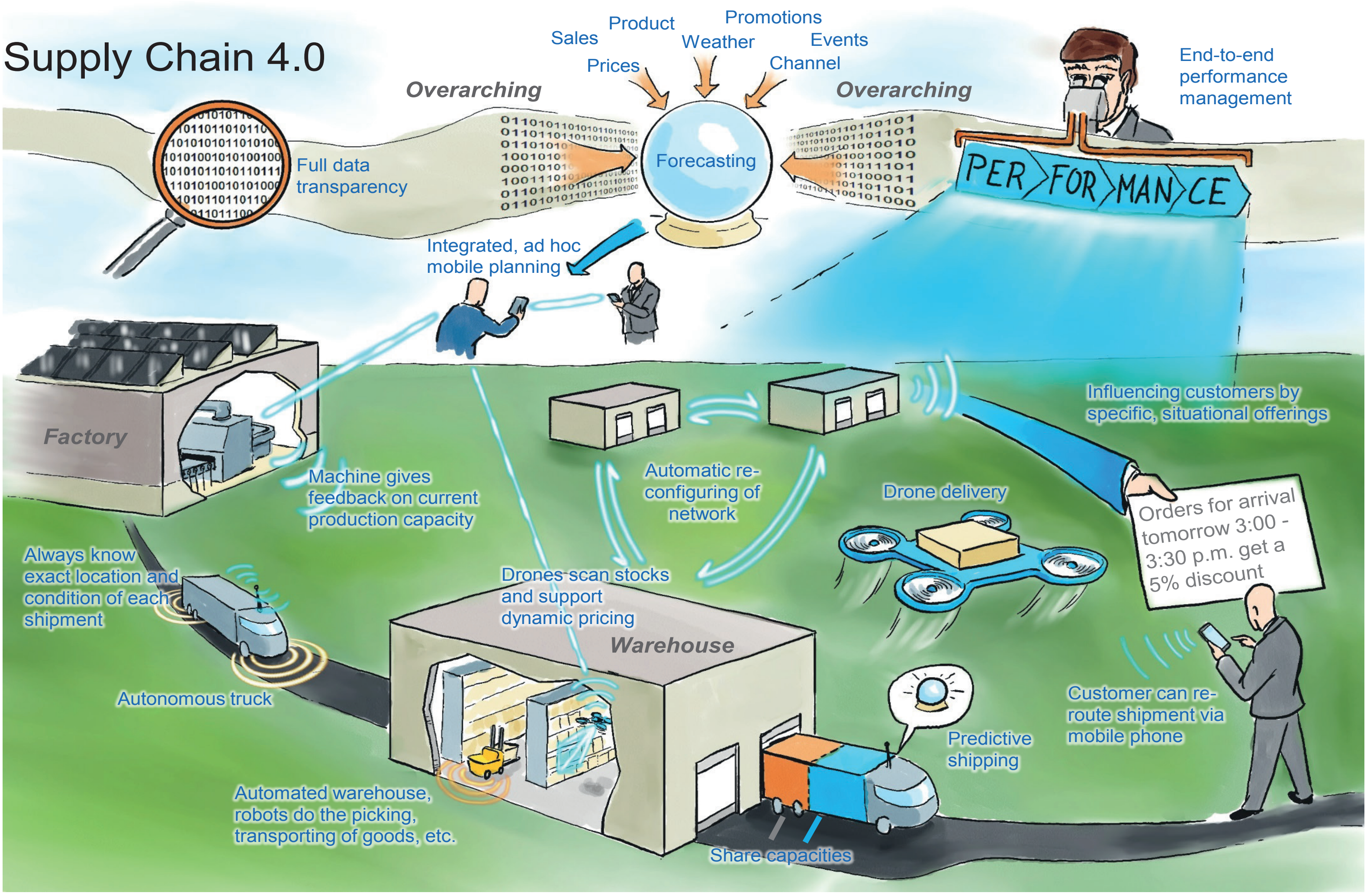
Trends in supply chain management

Industry 4.0 creates a disruption and requires companies to rethink the way they design their supply chain. Several technologies have emerged that are altering traditional ways of working. On top of this, mega trends and customer expectations change the game. Besides the need to adapt, supply chains also have the opportunity to reach the next horizon of operational effectiveness, to leverage emerging digital supply chain business models, and to transform the company into a digital supply chain.

Several mega trends have a heavy influence on supply chain management: there is a continuing growth of the rural areas worldwide, with wealth shifting into regions that have not been served before. Pressure to reduce carbon emissions as well as regulations of traffic for socioeconomic reasons add to the challenges that logistics are facing. But changing demographics also lead to reduced labor availability as well as increasing ergonomic requirements that arise as the workforce age increases.

At the same time customer expectations are growing: the online trend of the last years has led to increasing service expectations combined with a much stronger granularization of orders. There is also a very definite trend towards further individualization and customization that drives the strong growth of and constant changes in the SKU portfolio. The online-enabled transparency and easy access to a multitude of options regarding where to shop and what to buy drives the competition of supply chains.

To build on these trends and cope with the changed requirements, supply chains need to become much faster, more granular, and much more precise.



SOURCE: McKinsey

Vision of the future state

The digitization of the supply chain enables companies to address the new requirements of the customers, the challenges on the supply side as well as the remaining expectations in efficiency improvement. Digitization brings about a Supply Chain 4.0, which will be …

- **… faster.** New approaches of product distribution reduce the delivery time of high runners to few hours. The basis for these services is built by advanced forecasting approaches, e.g., predictive analytics of internal (e.g., demand) and external (e.g., market trends, weather, school vacation, construction indices) data as well as machine status data for spare-parts demand, and provides a much more precise forecast of customer demand. Forecasts are not carried out on a monthly basis, but weekly, and for the very fast-moving products even every day. In the future we will see "predictive shipping," for which Amazon holds a patent – products are shipped before the customer places an order. The customer order is later on matched with a shipment that is already in the logistics network (being transported towards the customer region) and the shipment is rerouted to the exact customer destination.

- **… more flexible.** Ad hoc and real-time planning allows a flexible reaction to changing demand or supply situations. Planning cycles and frozen periods are minimized and planning becomes a continuous process that is able to react dynamically to changing requirements or constraints (e.g., real-time production capacity feedback from machines). Once the products are sent, increased flexibility in the delivery processes allows customers to reroute shipments to the most convenient destination.

  New business models, such as Supply Chain as a Service for supply chain planning functions or transport management, increase the flexibility in the supply chain organization. Supply chain can be bought as a service and paid for on a by-usage basis instead of having the resources and capabilities in-house. The specialization and focus of service providers allow them to create economies of scale as well as economies of scope and also attractive outsourcing opportunities.

For example, we will see an "Uberization" of transport: crowd-sourced, flexible transport capacity, which will lead to a significant increase in agility in distribution networks.

- **… more granular.** The demand of customers for more and more individualized products is continuously increasing. That gives a strong push towards microsegmentation, and mass customization ideas will finally be implemented. Customers are managed in much more granular clusters and a broad spectrum of suited products will be offered. This enables customers to select one of multiple "logistics menus" that exactly fits their need.

  New transport concepts, such as drone delivery, allow companies to manage the last mile efficiently for single and high-value dense packages.

- **… more accurate.** The next generation of performance management systems provides real-time, end-to-end transparency throughout the supply chain. The span of information reaches from synthesized top-level KPIs, such as overall service level, to very granular process data, such as the exact position of trucks in the network. This range of data provides a joint information basis for all levels of seniority and functions in the supply chain. The integration of data of suppliers, service providers, etc. in a "supply chain cloud" ensures that all stakeholders steer and decide based on the same facts.

  In digital performance management systems, clean-sheet models for warehousing, transport, or inventory are used to set targets automatically. To keep the aspiration of targets also in case of supply chain disruptions, systems will automatically adjust targets that cannot be achieved anymore to a realistic aspiration level. We will see performance management systems that "learn" to automatically identify risks or exceptions and will change supply chain parameters in a closed-loop learning approach to mitigate them. That enables the automatic performance management control tower to handle a broad spectrum of exceptions without human involvement and to only leverage the human planner for the disruptive events/new events – with this, a supply chain is continuously developing towards its efficient frontier.

- **... more efficient.** Efficiency in the supply chain is boosted by the automation of both physical tasks and planning. Robots handle the material (pallets/boxes as well as single pieces) completely automatically along the warehouse process – from receiving/unloading to putting away to pick, pack, and ship. Autonomous trucks transport the products within the network. To optimize truck utilization and increase transport flexibility, cross-company transport optimization is applied to share capacities between companies. The network setup itself is continuously optimized to ensure an optimal fit to business requirements.

  To create an ideal workload in the supply chain, various transparency and dynamic planning approaches are leveraged to drive advanced demand shaping activities (e.g., special offers for delivery time slots with low truck utilization).

Digital waste prevents supply chains from leveraging the potential of Supply Chain 4.0

In today's supply chains many sources of digital waste can be found (in addition to the existing waste) that prevent the potential of Supply Chain 4.0. It is crucial to understand the sources of waste and develop solutions to reduce/avoid it in the future state. The sources of digital waste can be classified in three types:

1) **Data capturing and management.** Often, available data is handled manually (data collection in a system, paper-based data handling, etc.) and not updated regularly, e.g., master data on supplier lead time that is entered once (sometimes even only dummy numbers) and then remains unchanged for years. Another example in warehousing is advanced shipping notifications, which are received but not used to optimize the inbound process.

   On top of these examples, it is typically not clear which additional data could be leveraged to improve processes, e.g., sensing of supply disruptions – if the lead time of a supplier is continuously increasing, a warning should be sent out to make planners aware of the situation and enable them to mitigate supply disruptions at an early stage. In current systems, this signal will not be recognized and will lead to a lower supplier service level reported at the end of the month. If the worst comes to the worst, the issue will cause trouble in the assembly line replenishment and operational problems.

2) **Integrated process optimization.** Many companies have started to implement an integrated planning process, but very often this is still done in silos and not all information is leveraged to achieve the best planning result possible. In addition, it can frequently be observed that automatically determined planning or statistical forecast data is manually overwritten by planners. Especially for parts moving at medium or high speed, the manual overwrites usually have a negative impact on the forecasting accuracy. Beside the intracompany optimization, the process optimization between companies has not been fully leveraged yet and improvement potentials created by increased transparency are not realized.

   To get to the advanced level of integrated process optimization, the organizational setup, governance, processes, and incentives need to be aligned within and between partners in the supply chain.

3) **Physical process execution of humans and machines.** Nowadays, warehousing, assembly line replenishment, transport management, etc. is often done based on gut feeling, but not leveraging available data, e.g., to improve pick paths in the warehouse. Warehouse operations are still managed in batches of one to two hours, not allowing the real-time allocation of new orders and dynamic routing. Also, opportunities arising from new devices, such as wearables (e.g., Google Glass) or exoskeletons, are not leveraged.

Increasing operational efficiency leveraging Supply Chain 4.0

Supply Chain 4.0 will impact all areas in supply chain management. We have developed the McKinsey Digital Supply Chain Compass (see figure on next page) to structure the main Supply Chain 4.0 improvement levers and to map them to six main value drivers. In the end, the improvements enable a step change in service, cost, capital, and agility.

The McKinsey Digital Supply Chain Compass maps Supply Chain 4.0 improvement levers to 6 main value drivers

SOURCE: McKinsey

Planning

The future supply chain planning will largely benefit from big data and advanced analytics as well as from the automation of knowledge work. Two example levers with significant impact are "predictive analytics in demand planning" and "closed-loop planning."

Predictive analytics in demand planning analyzes hundreds to thousands of internal as well as external demand influencing variables (e.g., weather, trends from social networks, sensor data) with Bayesian network and machine learning approaches to uncover and model the complex relationships and derive an accurate and granular demand plan. These new technologies enable a significant improvement of demand forecast accuracy, often reducing the forecasting error by 30 to 50 percent. Also, the days of a "single truth" regarding the forecasting numbers are over – these advanced algorithms provide probability distributions of the expected demand volume rather than a single forecast number. This allows for targeted discussions, including upside potential and downside risks in the S&OPs, and advanced inventory management approaches.

Widely automated and fully integrated closed-loop demand and supply planning breaks the traditional boundaries between the different planning steps and transforms planning into a flexible, continuous process. Instead of using fixed safety stocks, each replenishment planning considers the expected demand probability distribution and replenishes to fulfill a certain service level – the resulting implicit safety stocks are therefore different with every single reorder. Another powerful feature of closed-loop planning is the integration of pricing decisions with the demand and supply planning; depending on the stock levels, expected demand, and capability to replenish, prices can be dynamically adapted to optimize the overall profit made and minimize inventories at the same time.

Physical flow

Logistics will take a huge step change through better connectivity, advanced analytics, additive manufacturing, and advanced automation. For example, as warehouses are being automated, we will see a significantly increasing amount of autonomous and smart vehicles, and 3-D printing changes warehousing and inventory management strategies completely.

The next generation of touch, voice, and graphical user interfaces and their quick proliferation via consumer devices facilitates a much better integration of machines in almost any process in warehousing operations. For example, the breakthrough of optical head-mounted displays, such as Google Glass, enables location-based instructions to workers, giving guidance for the picking process. Advanced robotics solutions have emerged for the improved picking of cases and single pieces, and the use of exoskeletons (that emulate the human physiology and can support straining manual movements) will have a major impact on warehouse productivity. In total, warehouse automations become much more holistic, with some warehouses being fully linked to production loading points, so that the entire process is carried out without manual intervention.

Autonomous and smart vehicles will lead to significant operating cost reduction in transportation and product handling and at the same time provide benefits regarding lead times and lower environmental costs. The use of self-guided vehicles in controlled environments (e.g., mines) or on-premise solutions (e.g., trains) as well as AGVs in warehouse environments are already operational and will further grow significantly in the near future. Autonomous trucks for use on public streets, however, are just being piloted in Europe and North America with promising results so far.

Besides the automation of warehouse processes, additive manufacturing will also have a significant impact on physical flows in the supply chain. For example, 3-D printing has become much more relevant for a broad range of business applications, such as local production of slowly moving spare parts or tools. This development is driven by an expanding range of printing materials, rapidly declining prices for the printers, and increased precision and quality. By now, the first production facilities that operate exclusively with 3-D printers have been established.

Performance management

Performance management is indeed changing tremendously. Whereas in the past, the generation of KPI dashboards was a major task and KPIs were only available at aggregated levels, now granular data is available in real time from internal and external sources. This moves the performance management process from a regular, often monthly process to an operational process aimed at exception handling and continuous improvement. For example, planners can be pointed to critical supply chain disruptions and further supported by an automatic handling of minor exceptions or potential solutions for the larger ones.

Automated root cause analyses are one approach for exception handling. The performance management system is able to identify the root causes of an exception by either comparing it to a predefined set of underlying indicators or by conducting big data analyses, leveraging data mining and machine learning techniques. Based on the identified root cause, the system will automatically trigger countermeasures, such as activating a replenishment order or changing parameter settings in the planning systems, such as safety stocks.

Order management

Two examples of how order management is improved are no-touch order processing and real-time replanning, which lead to lower costs through automation of efforts, higher reliability due to granular feedback, and superior customer experience through immediate and reliable responses.

No-touch order processing is the logical next step after implementing a reliable available-to-promise (ATP) process. Through an integration of the ordering systems, linking to ATP, and through an enrichment with order rules, the system can be used to fully automate the ordering process. The goal is to have a complete "no-touch" process, where no manual intervention is required between order intake and order confirmation. Very stringent order rules that have to be followed, and continuously updated master data are prerequisites.

Real-time replanning enables order date confirmations through instantaneous, in-memory replanning of the production schedule and the replenishment in consideration of all constraints. Therefore the supply chain setup is always up to date, leading to a very reliable planning base. On top, additional services can be offered to the customers, e.g., a faster lead time for a certain premium fee, so the customer can see the feasibility and the updated dates at a glance.

Collaboration

The supply chain cloud forms the next level of collaboration in the supply chain. Supply chain clouds are joint supply chain platforms between customers, the company, and suppliers, providing either a shared logistics infrastructure or even joint planning solutions. Especially in noncompetitive relationships, partners can decide to tackle supply chain tasks together to save admin costs, and also to leverage best practices and learn from each other.

Another major field within collaboration is the end-to-end/multitier connectivity. Where some automotive companies have already started collaborating throughout the entire value chain (e.g., from the cow farmer to the finished leather seat in the car), other companies still need to close this gap. The collaboration along the value chain allows for overall much lower inventories through an exchange of reliable planning data, a step change in lead time reduction through instantaneous information provision throughout the entire chain, and an early-warning system and the ability to react fast to disruptions anywhere.

Supply chain strategy

Following the need for further individualization and customization of the supply chain, supply chain setups adopt many more segments. To excel in this setting, supply chains need to master "microsegmentation." The granularization of the supply chain into hundreds of individual supply chain segments based on customer requirements and own capabilities designed in a dynamic, big data approach allows to mass-customize supply chain offerings. Tailored products provide optimal value for the customer and help minimize costs and inventory in the supply chain.

Impact of Supply Chain 4.0

Eliminating today's digital waste and adopting new technologies is a major lever to increase the operational effectiveness of supply chains. The potential impact of Supply Chain 4.0 in the next two to three years is huge – up to 30 percent lower operational costs and a reduction of 75 percent in lost sales while decreasing inventories by up to 75 percent are expected, at the same time increasing the agility of the supply chains significantly.

How did we calculate these numbers? The impact numbers are based on our experience from numerous studies and quantitative calculations – the three performance indicators are highly correlated, e.g., an improved inventory profile will lead to improved service level and lower cost.

- **Supply chain service/lost sales.** Low customer service is either driven by a wrong promise to the customer (e.g., unrealistic lead times), a wrong inventory profile (ordered products are not available), and/or an unreliable delivery of parts. Lost sales in addition occur if the required products are not available on the shelf or in the system – customers will decide to switch to another brand. This is true for both B2C and B2B environments.

  By significantly improving the way we interact with the customer, by leveraging all available POS data/market intelligence, improving the forecast quality significantly (up to more than 90 percent in the relevant level, e.g., SKU), and applying methods of demand shaping in combination with demand sensing to account for systematic changes/trends, the service level will increase dramatically and with this lost sales will decrease significantly.

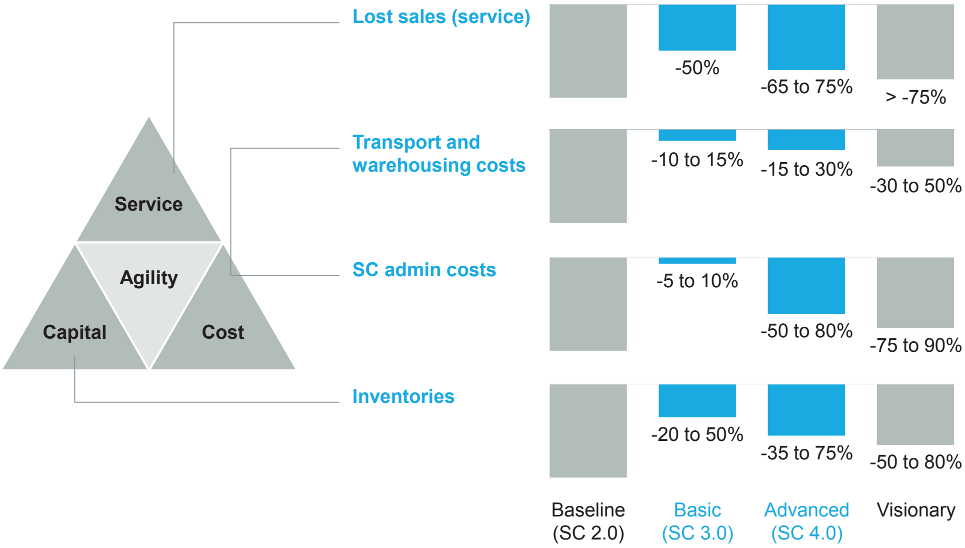
  We clearly need to keep in mind that industries like Pharma Rx, where the service level is often in the upper 90ies, will benefit less from the reduction of lost sales, but more from insights into the patient – and by providing individual service, they will be able to increase revenue.

- **Supply chain costs.** Driven by transportation, warehouse, and the setup of the overall network, the costs can be reduced by up to 30 percent. Roughly 50 percent of this improvement can be reached by applying advanced methods to calculate the clean-sheet (bottom-up calculation of the "true" costs of the service) costs of transport and warehousing and by optimizing the network – the goal should always be to have minimal touch points and minimal kilometers driven, still meeting the required service level of the customer. In combination with smart automation and productivity improvement in warehousing, on-board units in transportation, etc., the savings potential can be achieved. The remaining 15 percent cost reduction can be reached by leveraging approaches of dynamic routing, Uberization of transport, leveraging autonomous vehicles, and – where possible – 3-D printing.

- **Supply chain planning.** The planning tasks such as demand planning, preparation of S&OP process, aggregated production planning, and supply planning are often time intensive and conducted mainly manually. With advanced system support, 80 to 90 percent of all planning tasks can be automated and still ensure better quality compared to tasks conducted manually. The S&OP process will move to a weekly rhythm and the decision process will be built on scenarios that can be updated in real time. This accuracy, granularity, and speed has implications for the other elements, such as service, supply chain costs, and inventory. Systems will be able to detect the exception where a planner needs to jump in to decide.

- **Inventory.** Inventory is used to decouple demand and supply, to buffer variability in demand and supply. By implementing new planning algorithms, the uncertainty (the standard deviation of the demand/supply or forecast error) will be reduced significantly, making safety stock unnecessary. The other important variable to drive inventory is the replenishment lead time – with more production of Lot Size 1 and fast changeover, the lead time will be reduced significantly. Also, long transport time, e.g., from Asia to the EU or the US, will be reduced due to a significant increase in local-for-local production. In addition, 3-D printing will reduce the required inventory. We believe in an overall inventory reduction of 75 percent.

By applying Supply Chain 4.0 levers, huge potential can be unlocked in all supply chain categories



SOURCE: McKinsey

Capturing the value is a journey that can be started right away. Where it starts depends on the digital maturity of the current supply chain. The McKinsey digital walk-through helps companies appreciate the current digital maturity of the organization, create a sound understanding of the required levers to pull to reach the next performance level leveraging Supply Chain 4.0 tools to shape the road map for digitization, and estimate the potential impact.

The diagnostic tool assesses the supply chain systematically based on six value drivers and five assessment dimensions (e.g., data, analytics). It differentiates between three archetypes of maturity levels. Supply Chain 2.0 characterizes “mainly paper-based” supply chains with a low level of digitization. Most processes are executed manually. The digital capabilities of the organization are very limited and available data is not leveraged to improve business decisions. Supply Chain 3.0 describes supply chains with “basic digital components in place.” IT systems are implemented and leveraged, but digital capabilities still need to be developed. Only basic algorithms are used for planning/forecasting and only few data scientists are part of the organization to improve its digital maturity. Supply Chain 4.0 is the highest maturity level, leveraging all data available for improved, faster, and more granular support of decision making. Advanced algorithms are leveraged and a broad team of data scientists works within the organization, following a clear development path towards digital mastery.

The digital walkthrough leads to a maturity assessment along the major SC 4.0 dimensions and concrete recommendations going forward

Very high maturity | High maturity | Medium maturity | Low maturity | No maturity | x Score

	SC strategy		Planning					Physical flow					
	Network design	SC segmentation	Demand planning	Inventory mgmt	S&OP/ integrated business planning	Master planning	Scheduling	Warehouse operation	Transport operation	Assessment and tender of logistics	**Order mgmt**	**Collaboration**	**Performance mgmt**
Data	1	1	1	2	1	1	4	5	1	5	2	1	1
Analytics	3	1	2	1	5	4	1	1	3	3	1	4	3
Software/ hardware	4	1	5	1	1	3	3	2	1	2	1	3	4
People	1	1	1	2	1	1	4	5	1	4	2	1	1
Process	3	1	2	1	5	4	1	1	3	3	1	4	3

Enablers: SC organization, mindset and capabilities, SC IT

SOURCE: McKinsey

Transformation into a digital supply chain

The transformation into a digital supply chain requires two key enablers – capabilities and environment. Capabilities regarding digitization need to be built in the organization (see the chapter on capability building) but typically also require targeted recruiting of specialist profiles. The second key prerequisite is the implementation of a two-speed architecture/ organization. This means that while the organization and IT landscape are established, an innovation environment with a start-up culture has to be created. This “incubator” needs to provide a high degree of organizational freedom and flexibility as well as state-of-the-art IT systems (two-speed architecture independent of existing legacy systems) to enable rapid cycles of development, testing, and implementation of solutions. Fast realization of pilots is essential to get immediate business feedback on suitability and impact of the solutions, to create excitement and trust in innovations (e.g., new planning algorithms), and to steer next development cycles. The “incubator” is the seed of Supply Chain 4.0 in the organization – fast, flexible, and efficient.

Authors

Knut Alicke is a Partner from our Stuttgart office, leader of the EU Supply Chain Management Practice, and mainly focuses on supply chain planning and execution topics – his specific interest is Supply Chain 4.0/digital supply chain. Knut holds a PhD in logistics and a habilitation in SCM from the University of Karlsruhe. He is still active as a Professor at the Universities of Cologne and Karlsruhe. Before joining McKinsey he did work with ICON/ e2open.
Contact: knut_alicke@mckinsey.com

Jürgen Rachor is a Senior Expert of the Supply Chain Management practice and based in our Frankfurt office. He is part of the leadership team of the Supply Chain Management practice and leading our global Supply Chain Executive Academy. Jürgen's focus is especially on supply chain transformations, end-to-end supply chain planning, and Supply Chain 4.0. Before joining McKinsey, Jürgen worked at SAP focusing on strategic topics.
Contact: juergen_rachor@mckinsey.com

Andreas Seyfert is an Associate Principal from our Berlin Office and a core member of our Supply Chain Management Practice. His focus is on clients in discrete manufacturing and transportation & logistics industries. Andreas is deeply involved in our supply chain digitization initiatives. He holds a degree in transportation economics from Dresden University of Technology. Before joining McKinsey he did work with BMW AG.
Contact: andreas_seyfert@mckinsey.com

Supply Chain Management Practice
June 2016

Design contact: Visual Media Europe
www.mckinsey.com