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Lecture: *Supply Chain Management*

Supply Chain Management and Industry 4.0

An excerpt based on Martin Christopher's 'Logistics & Supply Chain Management' [1] with the attention on future changes due to technology innovations in Industry 4.0

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Industry 4.0 and the major technology changes

The term ‚Industry 4.0' originates on an initiative of the German government to ensure the competiveness of Germany in the next decades. This should be mainly achieved by technology changes like smart sensors, autonomous communication between products and machines, advanced data analytics and production or logistics simulation. The end result should be a 'Smart Factory' where all the physical processes are tracked by IT applications, communicate with each other, provide real time feedback and are able to optimize themselves automatically (with the help of artificial intelligence). [2]

Major technology changes in Industry 4.0 are:

- **'Smart sensors'** which are applied on products, machinery, containers, tools, means of transportation etc. and are able to measure physical conditions and intelligently react to it (sensor, microprocessor, port), for example the quality (e.g. for the cutting tool: 'do I need to replace the blade already?') or the place they are currently at (e.g. for the products: 'final assembly done, final quality management next')
- **'Digital twins'**: The simulation of a physical process with software in order to get real time data on current conditions, bottlenecks, problems or positioning. Advanced sensors and data models are needed in order to display production or logistics processes.
- **'Advanced data analytics'** to enable value adding analytics of the sensor data and simulation, which allow better forecasts, pattern detection or 'predictive maintenance' (e.g. 'cutting machine measures when to change the blade and processes it automatically')
- **'Autonomous communication & operation'** over the Internet between every physical part in the production or logistics process (e.g. every product, tool, container etc.).

1. Logistics, the supply chain and competitive strategy

At the beginning of the book 'Logistics & Supply Chain Management' Martin Christopher states that the basic ideas of supply chain management or logistics are not new ones. Having the right supplies (weapons, food etc.) in the right place at the

correct time during wars played a major role on who won the battle in the end. The high impact of logistics management on businesses and potential competitive advantages was only recognized in the last decades. According to Christopher there are many definitions of logistics, but it can be summarized as followed:

'Logistics is the process of strategically managing the procurement, movement and storage of materials, parts and finished inventory (and the related information flows) through the organisation and its marketing channels in such a way that current and future profitability are maximised through the cost-effective fulfilment of orders.'

Whereas logistics primarily focuses on the flow of products (and information) throughout the business, supply chain management additionally tries to link processes with suppliers and customers (the whole value chain). One example would be a connected information system, which provides facts about the inventory and the production schedule.

The concepts of Industry 4.0 should help with the current lack of information and in the best way optimize the process without human interaction. Sensors in the warehouse or directly on the product will recognize for example the current amount of stock. All the suppliers along the supply chain get the demand information in real time and are able to react to it. Lead times are shrinking and basically no inventory is needed.

Christopher Martin defines supply chain management as *'The management of upstream and downstream relationships with suppliers and customers in order to deliver superior customer value at less cost to the supply chain as a whole.'*
He adds that today a more accurate term for 'supply chain management' would be "demand network management" due to the fact that the chain should be driven by the market and instead of one supplier/ customer there is a whole network.

Cloud-based applications can help with the communication and information sharing in the complex network. Problems or demand changes can be noticed immediately and smart ERP systems might even re-schedule the production automatically ('Cloud Manufacturing').

Success in a market is primarily given if the company has either the price or the quality leadership/ value differentiation (or both, Porter's generic strategies).

According to Christopher supply chain management has the potential to get a company the competitive advantage by generating cost differentials between competitors (price leadership). Low costs are mainly achieved by the ‘experience curve” phenomenon developed by the Boston Consulting Group, which states that all costs decline as volume increases. Nevertheless logistics and supply chain management can enhance the productivity and efficiency which results in reduced unit costs in a significant way. Additionally supply chain management is able to offer a certain value differentiation regarding the service (f. ex. delivery time). The best example at this point is Amazon trying to achieve the ‘Same-Day Delivery’. The goal has to be a combination of high relative differentiation (value advantage) and low relative delivered costs (cost advantage) as it is shown in Figure 1.

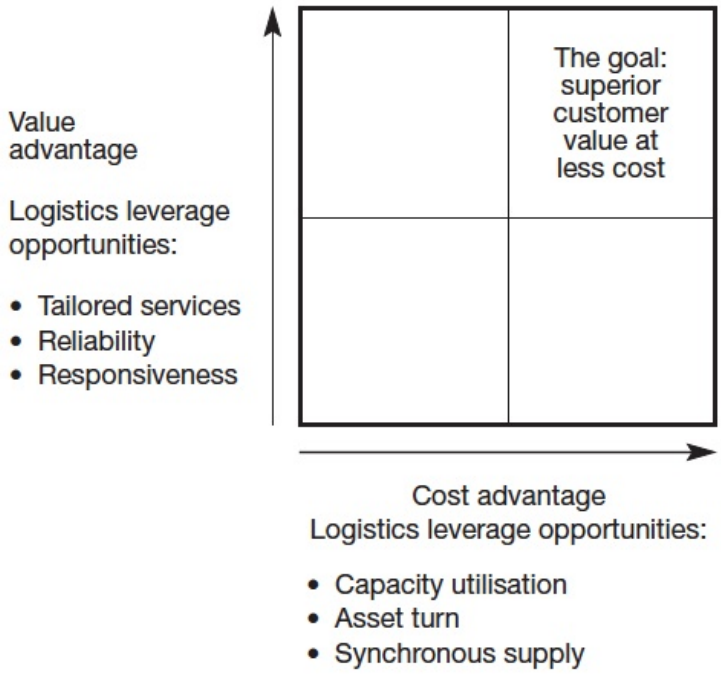

Figure 1: Gaining competitive advantage (p. 9)

Industry 4.0 was basically designed to keep the current competitive advantage of western nations or companies and maximize it. The right implementation of Industry 4.0 technologies can influence both the value and cost advantage significantly. Getting the demand in real time with sensors and connected IT applications along the supply chain increases the responsiveness immensely. Smart sensors help with the correct maintenance and therefor ensure the reliability (problems are identified before a major problem occurs). Sensors and data analytics also offer cost advantages due

to better knowledge of the current capacity and utilization. The demand is also known much earlier and inventory costs can be minimized.

An important way to gain value advantage is by analyzing the current value activities. Competitive advantage is only possible when the company performs primary activities (inbound logistics, operations, outbound logistics, marketing, sales, and service) and support activities (infrastructure, human resource management, technology development and procurement) in a more effective/ unique way than the competitors. Ineffective processes should be outsourced. The result is a value chain, which extends the boundaries of the business. Christopher even goes one step further by equaling the supply chain with the value chain. Competitive advantage is gained (or lost) by the 'whole extended enterprise'. The real competition today is supply chain against supply chain, not company against company.

Data models and simulations in the production and logistics are helping to reduce waste, to identify the value adding activates and bottlenecks. Due to sensors it is possible to recognize exactly how much time was needed for transportation, modification, quality control or assembly for a certain product. Advanced data analytics should be able to handle the huge amount of data measured by the sensors ('big data') and ideally offer smart solutions (e.g. 'care only one supplier for component xy, bottleneck expected, company yz offers the same with even cheaper prices' or 'it is not possible to achieve a takt time of 22 seconds, the process time of machine xy is to high, consider ordering a second one').

Therefore the mission of logistics management is the combination and improvement of the entire supply chain, from the extraction of raw materials to the end product at the customers. Ideally logistics management serves as a guideline for every business division (marketing, production, distribution, procurement) to approach the individual plans and steer the business in the right direction.
Whilst the theories of logistics focus mainly on the flows in the organization (stage 3), supply chain management achieves a more sufficient model by extending the principles down- and upstream (stage 4, Figure 2). The end results are lower costs overall and better service, which has the potential to enable a competitive advantage.

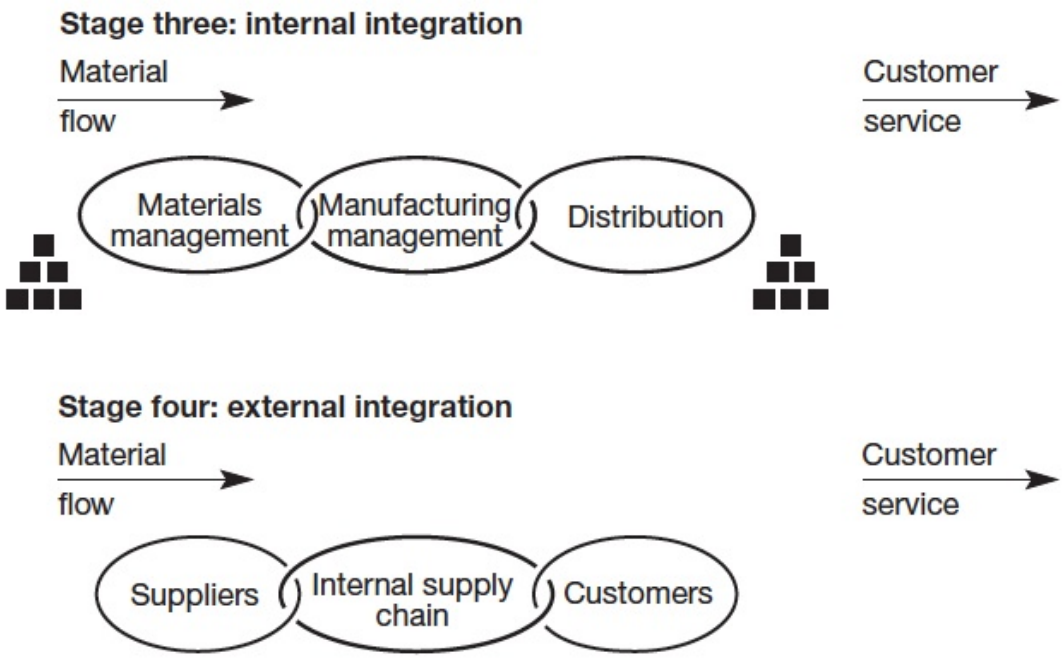

Figure 2: Integrated supply chain (p. 14)

There are various factors, which influence the competitive environment and change the priorities of businesses to keep their advantage. Due to the fact that the first edition of 'Logistics & Supply Chain Management' was published in 1992 we can already see most of the results of these changes. The **four challenges** he highlights at the beginning are:

- *The new rules of competition*
  - Service-based instead of product-based
  - Agile value delivery systems (shorter life cycles)
  - Competitive advantage = Product excellence x Process excellence
- *Globalization of industry*
  - Global companies that source and sell worldwide
  - National companies only for specific, local demand
  - Time-based competition = customer accepts substitute product, if their first choice is not available immediately (just-in-time delivery)
- *Downward pressure on price*
  - Overcapacity
  - Price comparability due to the internet
  - Value consciousness of the customers (brands lose importance)
- *Customers taking control*
  - Customers demand better quality and especially better service

The **‘4Rs’ principles** should help supply chain managers with accomplishing future goals and challenges.

- *Responsiveness*
  - Agility to react on the fast paced business environment and customer wants (demand-driven concept)
- *Reliability*
  - Improving supply chain reliability with the reduction of process variability (Six Sigma Methods)
- *Resilience*
  - Managing ‘critical paths’ (f. ex. dependence on one supplier)
  - Protect the supply chain against vulnerabilities
- *Relationships*
  - ‘Partnership sourcing’ to build collaboration with companies alongside the supply chain
  - ‘Win-win situation’ due to innovation sharing, improved quality, reduced costs, integrated scheduling of the production and delivery

Industry 4.0 supports the 4Rs and helps to overcome the challenges of today’s globalized industry. Sensors in the products, inventory etc. and the connection between customer and supplier allow a much faster identification of demand changes (Responsiveness). Smart sensors in the machinery, means of transport etc. enable better control and maintenance (Reliability). Digital Twins, the needed data models and sensors make it easier to find critical paths (bottlenecks) even before they are crucial. Autonomous communication, operation and information sharing not only enhances the effectiveness of the supply chain (intern and extern), it also creates a win-win situation due to better predictability, faster reaction time, reduced inventory or innovation sharing.

2. Logistics and customer value

Regarding the 4’Ps in marketing the focus has mainly been on product, price and promotion. Today customers tend to focus on product availability (place) rather than brands. To satisfy the demand of the service-sensitive customers lead times have to get shorter and demand changes need to be recognized earlier.

With the aid of mobile applications or websites it is easier to identify the locations of the customers and therefor adjust the service and marketing to the individual needs.

$$\text{Customer value} = \frac{\text{Perceptions of benefits}}{\text{Total cost of ownership}}$$

Figure 3: Customer value calculation (p. 29)

The customer value is the most important factor for success and customer satisfaction and can be calculated by the perceptions of benefits divided by the total cost of ownership (Figure 3). 'Total cost of ownership' rather than 'price' is used here because in most transactions there will be costs other than the purchase price involved like inventory carrying costs, maintenance costs, running costs, disposal etc.

$$\text{Customer value} = \frac{\text{Quality} \times \text{Service}}{\text{Cost} \times \text{Time}}$$

Figure 4: Detailed customer value calculation (p. 30)

In a more detail approach displayed in Figure 4 the benefits can be separated in quality (functionality, performance and technical specification of the offer) times the service (availability, support and commitment provided to the customer). The total cost of ownership consists of cost (customer's transaction costs including price and life cycle costs) multiplied by the time taken to respond to customer requirements, e.g. delivery, lead times.

Customer service is an important factor often forgotten to be a significant part of the customer value and basically provides ‚time and place utility'. Achieving the demanded 'Availability' is complex due to various factors like delivery frequency and reliability, stock levels and the order cycle time. For better measurement of the customer service, it can be divided in terms of time:

1. *Pre-transaction elements:* written statements of service policy, adequacy of organizational structure and system flexibility
2. *Transaction elements:* product and delivery reliability
3. *Post-transaction elements:* supportive of the product while in use, for instance, product warranty, parts and repair service, procedures for customer complaints and product replacement

The importance of customer service can be recognized by observing the consequences of being out of stock. According to research over a quarter buy a different product, 31% shop somewhere else and 2/3 of buying decisions are made during the purchase (only when they see the product). Figure 5 should display the impact of customer service and supply chain management on marketing effectiveness and therefore the market share and customer retention.

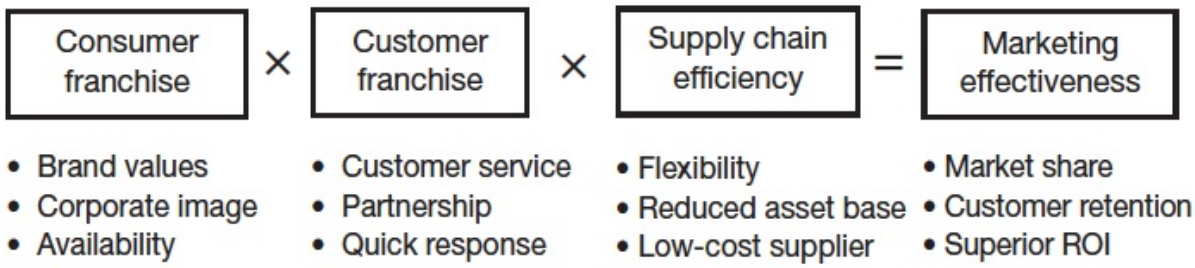

Figure 5: The impact of logistics and customer service on marketing

Theodore Levitt was the first who said that ‘people, don’t buy products, they buy benefits’. Sure the core product with certain quality, features, technology is expected, but the service surround (delivery lead time and flexibility, reliability, after-sales support) increases in significance.
Classic definitions of marketing place importance on ‘getting and keeping customers’. Resent research ascertained that keeping customers and even building up a relationship is more important due to the fact that they will buy more and more in the future (customer retention, lifetime value).
For this reason the focus of the supply chain has to be on the customer needs (‘demand chain management’) and therefore designed from the customer backwards (e.g. just-in-time delivery). In order to achieve market-driven supply chains the first step is identifying ‘service segments’ (groups who have similar service needs). This depends on the perception of the customer’s point of view (on-time delivery).

Christopher explains a three-step method of service segmentation:

1. Identify the key components of customer service as seen by customers themselves.
    a. What are the key sources of influence upon the purchase decision
    b. Small research program based on interviews with the identified target customers (f. ex. service importance, marketing mix elements)
2. Establish the relative importance of those service components to customers.

   a. Ask the target customers to order the service components (from step 1) in order of importance
   b. Trade-off technique: Present different combinations and ask the target customers to rank them
3. Identify ‘clusters’ of customers according to similarity of service preferences.

Knowing the needs of the customers especially regarding the service level can play a major role whether a company succeeds or not. With advanced data analytics the company is able to identify the total cost of ownership in detail and the service segmentation for every customer. This is the basis to know the customer value of a product and also the service level desired.

Further on Christopher provides a definition of customer service objectives:
‚The whole purpose of supply chain management and logistics is to provide customers with the level and quality of service that they require and to do so at less cost to the total supply chain.’

An established method of measuring the service objectives is with the concept of the perfect order. Separated in on-time, in-full and error-free percentages and multiplied with each other it is possible to identify the likelihood of a perfect order.
All companies need to keep in mind that 80 percent of the profit is generated by 20 percent of the customers, or 80 percent of cost is caused by 20 percent of the customers. This is called the Pareto Law, or 80/20 rule. For this reason it is important to identify the profitability of the customers in the first place and then improve it in general.

The probability can be characterized in the usual bell-shape (‘normally’ distributed, Gaussian bell curve). For this reason on 68% of the occasions the demand is within plus/ minus one standard deviation either side of the mean (on 95% plus/minus two standard deviation, on 99% plus/minus three standard deviation). Achieving a service level of 84 per cent could be achieved by setting the stock level one standard deviation greater than the mean (Figure 6).

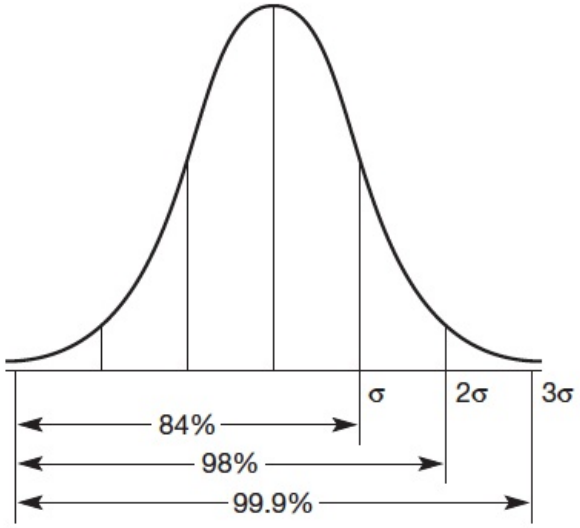

Figure 6: Service level and the normal distribution (p. 45)

If it is possible to achieve faster transportation or to get earlier information about customer requirements, the reliance on inventory could be deceased immensely. Thus the cost of service is lower at the same service level.

According to the Pareto Law we can assume that approximately 20% of our products generate 80% of our profit and 20% our customers are responsible for 80% of our profit. For this reason it is important to categorize the products and the customers and to identify the appropriate service level (similar to Figure 7).

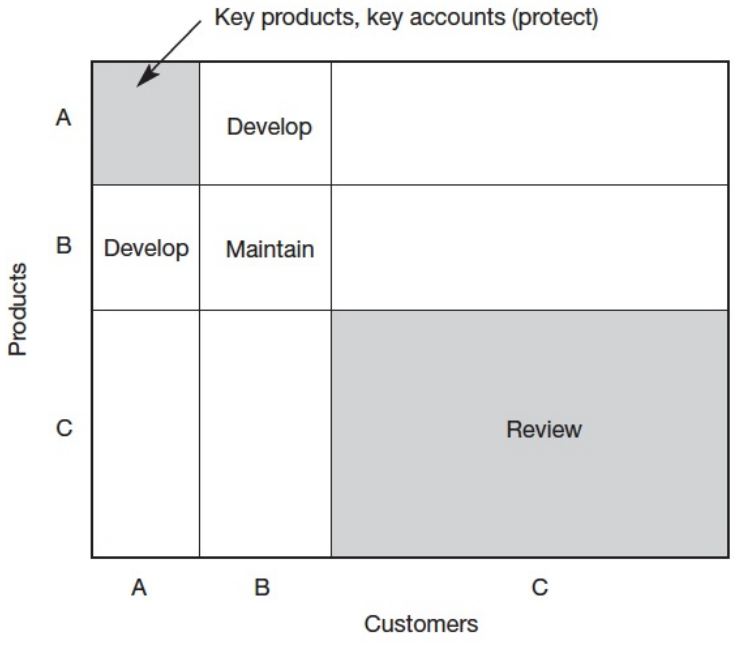

Figure 7: Customer Service and the 80/20 rule (p. 49)

The service standards should be defined by customer research and benchmarking. Key areas are order cycle time, stock availability, order-size constraints, ordering convenience, frequency of delivery, delivery reliability, documentation quality, technical support etc. A composite service index is a good management tool to identify an overall service score based on customer service wants and the actual performance level of those service elements.

3. Measuring logistics costs and performance

Supply chain management has a major impact on the financial situation of a company and can alter the cash flow or the ROI in a significant way. Nevertheless many companies only focus on profit and forget the influence of the 'capital employed'. The 'iso-curve' in Figure 8 shows the impact of both factors (margin and asset turn) on the ROI.

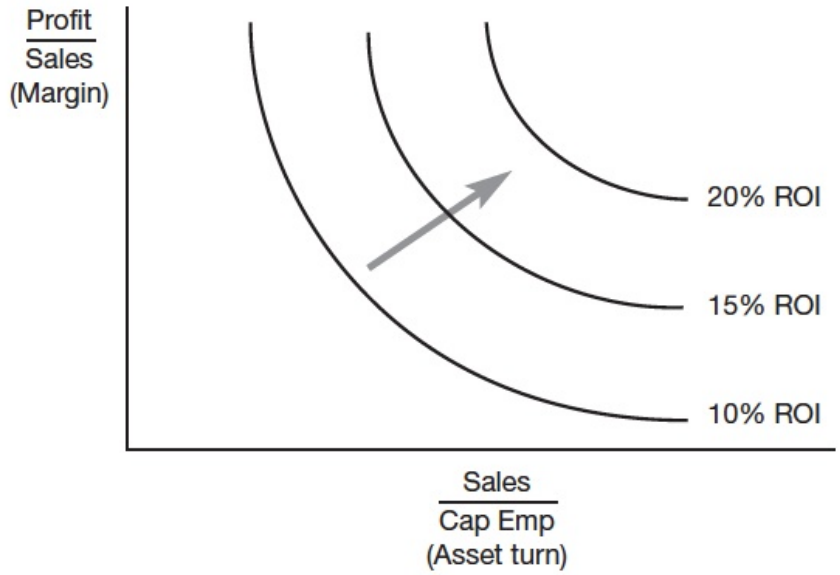

Figure 8: The impact of margin and asset turn on ROI (p. 59)

There are various opportunities to influence the ROI with logistics. Customer service or logistics efficiency have an impact on the profit, whereas invoice accuracy, just-in-time logistics or asset utilization affect the capital employment. The ROI can not only be influenced by logistics management; even the balance sheet can be affected.

Logistics variables like order cycle time or order completion rate alter cash and receivables. Inventory and equipment have a direct influence on the balance sheet. The financing options for the previous named assets or the purchase order quantities are represented in the liabilities of the balance sheet.

Today the corporate performance is primarily measured by the shareholder value. A simple method to determine this parameter is by calculating the net present value of future cash flows. In the recent years the economic value added (EVA) was used more frequently to analyze the shareholder value. Figure 9 shows the calculation of the EVA. To measure the wealth of a company the net present value of future EVA's would have to be evaluated. This value is called the market value added (MVA) and can be defined as stock price multiplied by the issued shares less the book value of total capital invested. Logistics variables like capital-intensive logistics facilities or lengthy pipelines have a significant impact on the EVA and therefore the shareholder value.

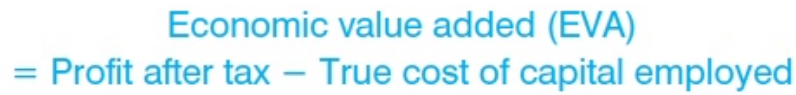

Figure 9: EVA calculation (p. 62)

Christopher states that there are five major drivers for the shareholder value, which can also be influenced (directly or indirectly) by supply chain management: revenue growth, tax minimization, fixed capital efficiency, operating cost reduction and working capital efficiency. According to research generating a high amount of cash flow in the early stage results in a significantly enhanced cash flow later on.

To minimize the costs of logistics a detailed cost accounting system is needed and optimized trade-offs are possible (more service, but even higher sales revenue). Crucial is the minimization of the total costs of the distribution network by finding the most cost-effective combination of different logistics parameter (inventory, local delivery costs, outlet costs etc.). Inventory has an above-average impact on the total logistics costs due to factors like cost of capital, storage and handling, insurance, management costs etc. There are principles to follow which enables accurate logistics costing. Firstly it should show the cost for the customer service provided and secondly a revenue and cost analysis should be possible for individual customer type, distribution channel or market segment. Defining different 'supply chain missions' helps to set customer service goals (functional area e.g. transportation, production, sales etc.) for a specific market/product and measure their success.

Identifying the true cost and revenue belonging to a certain customer is the best way to measure customer profitability. The analysis is done by subtracting attributable and avoidable costs like sales calls, transport costs, order processing costs from the net sales value of the regarded company. It is then possible to categorize the different customers according to their profitability and create individual service strategies (Figure 10).

If you have an actual digital twin of your production and logistics it is way easier to try out new adaptions and immediately see the results. Through sensors it is not only possible to identify the critical paths and waste really fast, the data can also be used for the accounting system. Thus the inventory has a major impact on the costs and therefore the ROI, it is crucial to keep the stock on a minimum level.

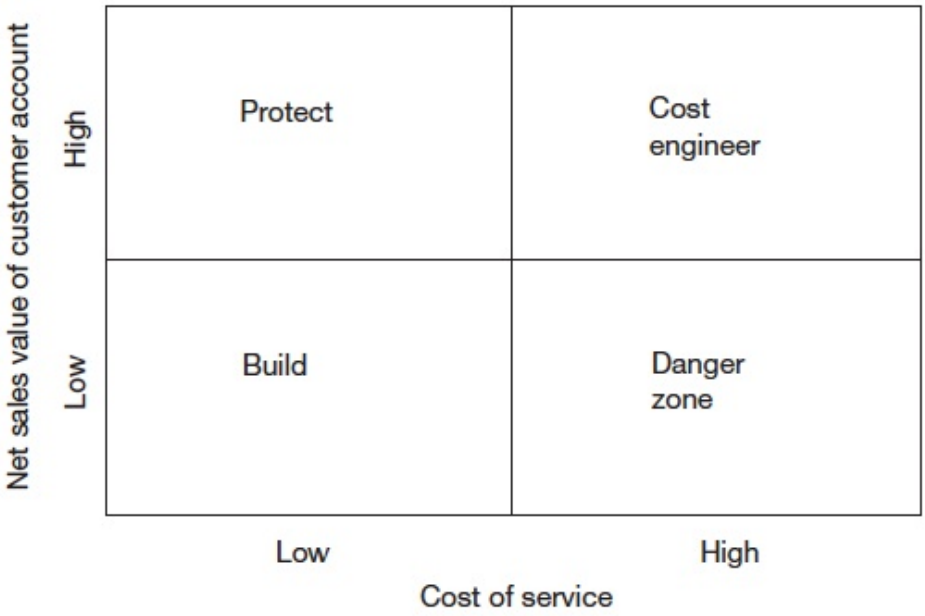

Figure 10: Customer profitability matrix (p.77)

The direct product profitability (DDP) is a customer-based cost analysis application which not only identifies the purchase price, but also the hidden costs involved like storing the item and order processing. This concept is also known as the *total cost of ownership* and is the key parameter to be analyzed and adjusted in order to achieve long-term success.

4. Matching supply and demand

Supply chain management has the simple task to supply the demand, but various factors of uncertainty and the business environment lowers the forecasting accuracy. The first problem is the '**lead time gap**', which emerges due to the fact that customers cannot wait for the procurement, manufacturing and delivery of a certain product (difference between the logistics lead time and the order fulfillment). Conventional businesses try to solve this problem by stacking up inventory based on forecasts. A more cost-effective way is reducing the lead-time gap by approaching the logistics lead-time to the customer's order cycle due to earlier visibility of requirements or leaner processes.

One important step to achieve this goal is setting the demand penetration point further upstream (also known as the de-coupling point). Downstream of this point everything is demand-driven and ideally the strategic (or generic) inventory is stored here. The best way to get more visibility of demand is by sharing information alongside the whole supply chain.

If a better visibility is achieved and the velocity to produce/ship is higher (lean management), the costs for inventory and capacity can be reduced immensely (better responsiveness).

Today advanced demand management and planning concepts try to anticipate the real demand and enable cost-effective adjustments. Solely forecasting, increasing inventory and then reacting is replaced by sales and operations planning (S&OP). On-time and in-full deliveries with minimum inventory should be managed by aggregate demand forecasts modified with demand intelligence, 'rough cut' capacity plans, execution at individual item (SKU) level against demand and performance measurements (lead-time gap).

Collaborative planning, forecasting and replenishment (CPFR) between companies (buyer/supplier) should enable vendor-managed inventory (VMI). The supplier uses the information directly from the point-of-use or the point-of-sales and concludes the shipping quantities. The benefits range from reduced capital invested (optimized production, reduced storage capacity) to decreased costs (inventory, wastage, overtime, transportation) and increased value (better availability, improved consumer satisfaction).

Closing the lead-time gap plays a major role to match supply and demand. Thus visibility of the whole supply chain is a key factor to reach this goal, sensors and data analytics enables the simulation of the whole value chain. Even the smallest changes can be recognized real time and processes can be modified in seconds. Favorable

the whole supply chain network is connected and even autonomous adaptions are possible with smart sensors and communication between machine and products.

5. Creating the responsive supply chain

Due to shorter product and technology life cycles, more product changes to stay competitive and a greater variety demanded by consumers, agility regarding volume and variety change is more important than ever for businesses. Lean manufacturing works well for mass production and standardized products, however if customized product variants for smaller market segments are needed, agility comes into play.
Choosing the right supply chain strategy in Figure 11 depends on supply characteristics (long/ short lead time) and demand characteristics (predictable/ unpredictable).

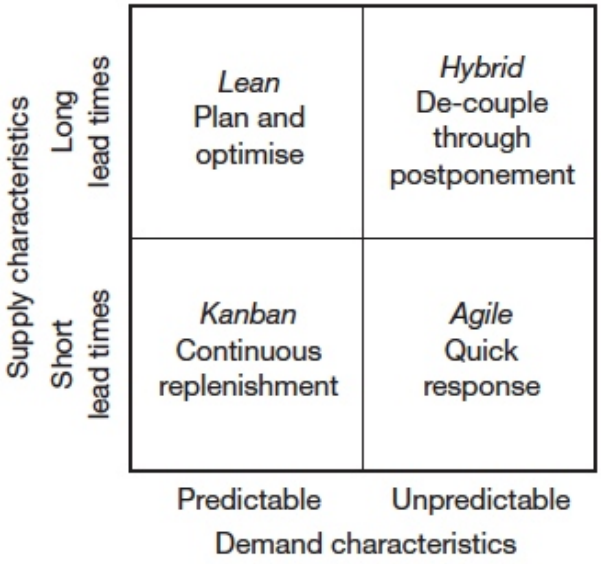

Figure 11: Generic supply chain strategies (p. 101)

Agile networks have been made possible due to advanced information technology where data is automatically shared and virtual, information-based supply chains are generated.
Shorter lead times enable pull strategies, or even just-in-time delivery where products are only produced when there is real demand downstream. Conventionally push systems have been used where products were produced in batches according to forecast, reorder points (ROP), in economic order quantity (EOQ) and stored in buffers. The EOQ formulae is easy to calculate and push strategies with advanced forecast techniques have been used for decades, nevertheless in the end there is always a lot of unproductive inventory which results in reduced working capital.

The Kanban production system focuses exactly on this problem. Only the needed demand of products and components is produced and for this reason the buffers are only as big as the component's replacement time (minimized stocks). Bottlenecks and quality problems during the production operation become apparent and can be eliminated. The 'economic batch quantity of 1' is the ultimate goal which should be achieved due to reduced set-up and ordering costs.
If the demand is unpredictable and short lead times are needed, agility is the most important factor. Christopher presents four basic principles on how to start the agile supply chain:

1. Synchronize activities through shared information
2. Work smarter, not harder – focus on value adding processes
3. Partner with suppliers to reduce in-bound lead times
4. Seek to reduce complexity (by standardization and simplification)
5. Postpone the final configuration/ assembly/ distribution of products
6. Manage processes not just functions (autonomy to self-managed process teams)
7. Utilize appropriate performance metrics (f.ex. 'perfect order achievement' or effectiveness due to advanced responsiveness)

Responsiveness is getting more important in order to become truly market-driven. Characteristics of a responsive business are agile suppliers with shared information and align processes, close relationship to customers to get real demands and advanced lean and agile paradigm applied in the business operations (like de-coupling or postponement).

Choosing the right supply chain strategy is getting more and more important. In the last decades efficient lean systems have been the favorable strategy. Nevertheless lead times are getting shorter and the demand is getting even more unpredictable. The most effective strategy for this scenario is an agile system. Those systems are only possible due to the developments in IT technology in the last couple of years. Only through sensors, data analytics and shared information it is possible to have a full transparency over the supply chain. Having a digital twin of the whole value chain would be the required goal in order to react without delay on changes or problems.

6. Strategic lead time management

The time-sensitivity of customers rises and if the preferred brand cannot meet the demand, substitute brands with equal quality will be bought instead. The reasons for this development are the shorter life cycles, customers' drive for reduced inventories

(just-in-time delivery of suppliers as the order-winning criterion) and volatile markets which make reliance in forecasts dangerous.
For the customer the most important lead time is the time between the order and the delivery (order-to-delivery cycle). Whereas for the supplier the time it takes to convert the order into cash is crucial (cash-to-cash cycle).
Logistics pipeline management tries to link manufacturing and procurement to achieve lower costs, higher quality, more flexibility, faster response time and therefor reduce lead times significantly. Flowcharting the supply chain processes and identifying the value-adding activities is a major step to improve the overall efficiency.
Figure 12 shows how the reduction of non-value-adding time (like excessive inventory, extended set-up, sequential order processing) is able to boost the efficiency and shorten the lead-time. Furthermore it is important to recognize that only optimizing the logistics network as a whole and focusing on total throughput time results in the most time- and cost-effective solution. So called 'bottlenecks' characterize the slowest activities (machines, workers or information flow) in the logistics chain and therefore often display the problem why a certain takt time cannot be achieved.

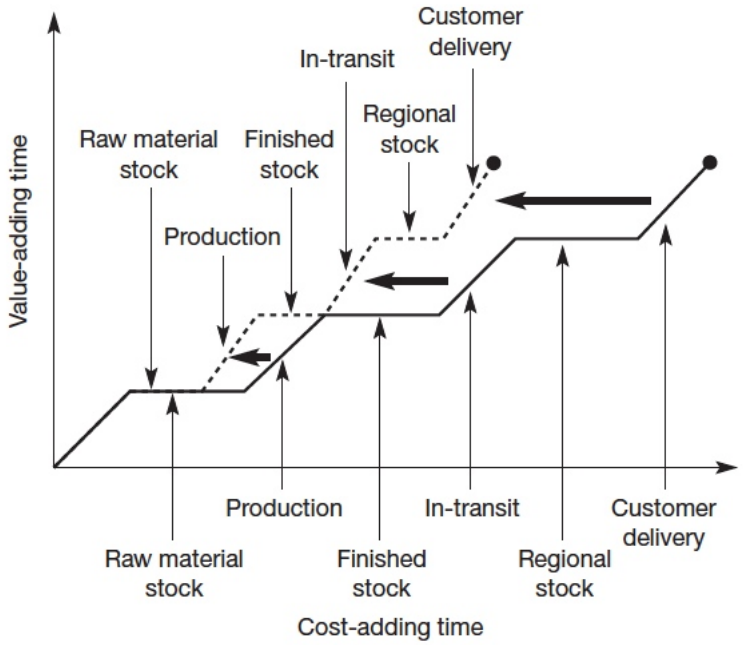

Figure 12: Reducing non-value adding time improves service and reduces cost (p. 133)

As mentioned before digitally simulating the whole supply chain (and production) with real time sensors displays the best chance to minimize lead times. It is therefor

possible to exactly identify bottlenecks, time waster, inventory, unnecessary handling etc. Non-value adding time can be reduced further and agile systems can become reality.

7. The synchronous supply chain

In order to achieve a short end-to-end pipeline time and high responsiveness information need to be shared along the whole supply chain and enable a synchronized network. Key processes that need alignment in a synchronous supply chain are planning and scheduling (material, capacity), design (mechanical, supply chain), new product introduction, product content management, order management, sourcing and procurement.
Creating partnerships or even ‘extended enterprises’ enhances the responsiveness and effectiveness due to value-added exchange of information in so called *Extranets*. New technology enables a direct linkage between the customer and the supplier, which leads to an immensely improved reaction time.

One example would be the company IntelligentX, which is trying to combine an AI with beer brewing. They developed an application where every customer can give feedback on the beer. Further autonomous data analytics try to find trends and influence directly the production process to satisfy the customer needs and wants. [3]

Information technology plays a key role and productive applications can be found in every department: customer service, marketing channel, information retrieval, supplier relationship, financial transactions, building strategic alliances, electronic distribution, internal communication, sales force automation, human resources and employee relations.
Sensors should help to identify the demand in real time (f. ex. in the store) and send the information to the supplier (also termed as ‘Quick Response’ logistics). Lead times and inventory can be reduced drastically.
The demand for quick response rises and can be only achieved due to a certain degree of flexibility. Flexible manufacturing systems (FMS) are able to minimize set-up time (to change the volume or variant) from hours to minutes mainly by new technology, simply focusing on the problem or by questioning the conventional wisdom (‘single minute exchange of die’ or SMED). From an overall point of view it can be said that the model ‘economies of scale’ shifts to the ‘economies of scope’ and as a consequence enhances the importance of changeovers due to smaller quantities and a wider range (even termed as *mass customization*).

Forrester created a production/distribution model to show that small disturbances in the supply chain can become magnified in a short time period. One example revealed the problem that discounts (or other promotions) are often not profitable due to the fact that this generates a distortion in the demand which escalades further upwards the supply chain (10% customer demand, 40% more demand for the supplier).

Thus products and machines will be able to communicate with each other and autonomously operate the set up time can be reduced even further. Smart sensors are getting more famous due to the fact that all the data needs to be digital in order to keep track or even enable smart objects that communicate with each other.

8. Complexity and the supply chain

Christopher states that supply chains can result in high complexity and therefore reduce certainty and forecast accuracy. Reasons are the *network complexity* due to external suppliers and unawareness of second or third tier suppliers, the *process complexity* with non-value adding time components and the *range complexity* due to numerous variants of a product. Furthermore there is the *product complexity* due to all the different components and subassemblies, the *customer complexity* by means of non-standard service options or *supplier complexity* because of too many partnerships with suppliers. *Organizational complexity* arises in most companies due to hierarchical organization charts of all the functions and departments in a vertical spanning tree (instead of high effective, agile teams). Getting information about external and internal processes is an important part to achieve a high efficiency, nevertheless high amounts of data result in certain *information complexity.*

Complexity is often followed by an increase in costs, whether directly due to investments in new applications or indirectly due to overhead costs or inventory. Using the 80/20 (Pareto principle) and focusing on the 20% best customers/ products (and rationalizing the 20% most un-effective ones) results in an overall higher profitability and reduces the complexity.

Christopher adds that product design is one of the biggest influencers regarding costs due to the impact on the whole supply chain. Products with high manufacturing complexity, low component commonalities, need for special (offshore) supplier, unreliable supply sources or after sales support increase the time-to-market and lead times, add complexity, deny late customization, higher supply chain vulnerability and after sales support.

Reducing the complexity has to be a major issue for supply chain managers and the author offers a five-stage process on how to manage complexity:

- Understand the sources of complexity (categorizing)
- Undertake Pareto 80:20 Analysis
- Focus on the ‘long tail’
- Which elements of complexity add value and which do not?
- Seek to eliminate non-value adding complexity

The best sensors have no use at all if the data is not analyzed correctly or clearly. The amount of sensors used in the production is rising drastically and therefore the amount of data (also termed ‘big data’). Intelligent use of new technologies decides how complex the supply chain will be in the end. The danger is setting up too many sensors without evaluating and connecting the data.

9. Managing the global pipeline

Global companies try to get into different markets worldwide and use the economies of scale to reduce costs. Nonetheless there are challenges like the need for local product adaptations or cost- and time-effective management of the complex supply chain network. The key to success of global companies is to find the best trade-off between various factors like transport, material, inventory and production (Figure 13).

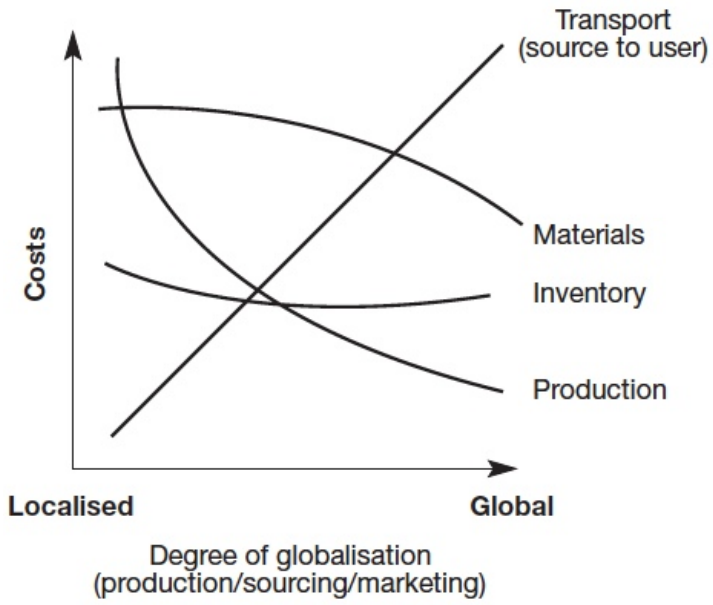

Figure 13: Trade-offs in global logistics (p. 172)

With digital simulations of the supply chain the right trade-offs are easier to identify. The change of a few parameters can be simulated. The real outcome of decisions can be approximately estimated based on those simulations.

More and more companies tend to expand globally due to lower trade barriers and better global infrastructure. This leads to overcapacity and lower costs, so staying competitive the focus has to be on more effective supply chains. Established global logistics strategies are the focused factories: “by limiting the range and mix of products manufactured in a single location the company can achieve considerable economies of scale“, centralized inventories to reduce the total stock requirement and postponement where the final configuration of standardized components takes place when the final market destination is known.
Supply chain event management (SCEM) helps to achieve a certain visibility by placing measurement points along the supply chain. If deviations occur, the application sends a signal and the functional manager can react to it.

Placing measurement points along the supply chain is basically where Industry 4.0 excels. A lot of parameters are measured today as well, but are then often saved in Excel charts and data analysts are hired to evaluate them. With smart sensors or advanced data analytics these data should be evaluated automatically and intelligent solutions should be offered or even performed autonomously. The goal is reducing routine jobs to the minimum and save the time for the team to focus on the core challenges.

Christopher states that there are several general principles emerging on how to organize global logistics:

- The strategic structuring and overall control of logistics flows must be centralized to achieve worldwide optimization of costs.
- The control and management of customer service must be localized against the requirements of specific markets to ensure competitive advantage is gained and maintained.
- As the trend towards outsourcing everything except core competencies increases then so does the need for global co-ordination.
- A global logistics information system is the prerequisite for enabling the achievement of local service needs whilst seeking global cost optimization.

The difficulty is finding the right combination between global and local management. “Think global, act local” is the statement that is becoming more and more popular and clarifies the need for global co-ordination of inventory, costs, production and transportation whereas local management should focus on customer service, local sales and delivery.

Industry 4.0 technologies can enrich both global and local management. ‘Think global, act local’ will also be the mantra in the future, but IT applications enable better knowledge of the customer service needs or the demand. Optimizing global components of the supply chain like inventory, costs, production or transportation is going to be simplified due to advanced simulation software. The local management on the other hand uses data analytics to know exact details about the local customers, their buying behavior and their service preferences.

Global sourcing and production had a huge importance for many companies; nonetheless a lot of those global players tend to rethink the strategy due to higher costs than primarily expected (exchange rate fluctuations, transportation costs, increased inventory, quality problems, loss of intellectual property and environmental issues).

10. Managing risk in the supply chain

As explained in earlier chapters the demand is getting more and more uncertain due to shorter product- and technology life cycles. Unforeseen events, which damage the supply chain, also have an impact on the whole financial situation of a company. The vulnerability increases due to the focus on ever-leaner supply chains with just-in-time (JIT) delivery instead of agile, responsive systems (efficiency rather than effectiveness). Globalization, focused factories and centralized distribution cause additional risk due to the fact that the calculations are mostly based solely on production costs and supply chain costs like longer lead times or inventory buffer are ignored. Outsourcing activities and focusing on the core competencies should help to achieve competitive advantage; nevertheless the supply chain network is getting more and more complex and control over certain tasks is lost. Overall the trend of supply base reduction has a lot of advantages, but solely relying on one supplier results in increased risk as well.

A supply risk profile should help to identify the vulnerable parts of a supply chain. An established approach is analyzing the five sources of risk: supply risk, demand risk, process risk, control risk and environmental risk.

Digital twins and advanced data analytics will be used to minimize any risk in the supply chain. The goal is recognizing problems before they even occurred. Technology changes may be able to avoid risks in the supply chain. Smart sensors may even make it possible that machines solve problems autonomously. The only risk that even increases is the danger of cyber attacks or breakdowns. Cyber security will have an incredible high priority in ‘Smart Factories’.

In the end of this chapter Christopher explains a guideline on how to manage supply chain risk in a seven stages management process. First it is important to understand the wider supply chain network, downstream, but also upstream above the first tier suppliers. Second the supply chain has to be improved with a focus on simplification, process reliability and reduction of process variability and complexity. Six Sigma is a powerful methodology to reduce especially the process variability. Third the critical paths have to be identified due to common characteristics like long lead times, single source of supply, dependence on specific infrastructure, bottlenecks or nodes with high risk. Failure mode and effect analysis (FMEA) is a useful tool to observe each link or node and evaluate the degree of risk and impact. Fourth the critical paths have to be managed. Is it possible to follow certain action steps in case of failure or does the whole supply chain need to be re-engineered? Fifth the network visibility has to be improved by advanced supply chain event management (SCEM) and emerging technologies like RFID tags. Sixth a supply chain continuity team should be established, ideally cross-functional with the needed skills of risk management and with the supply chain director on board. Seventh working together with suppliers and customers and introducing risk management can significantly enhance the protection of the whole supply chain. Even the best supply chains are not safe against heavy turbulences or unexpected attacks. For this reason a certain degree of resilience (return back to its original state after being disturbed) is needed and therefore agile concepts are implemented.

11. The era of network competition

According to AMR Research there are six consistent characteristics of the companies with the best supply chains. They all have an ‘outside-in focus’ (demand-driven supply chain), a close connection during the innovation process between product

design, manufacturing and logistics, an extended supply chain network with close relationships and good trade-offs across the business with the focus on key performance indicators (KPIs). Furthermore these companies have the right attitude towards external partnerships and they recognize the need for high talented and skilled people who can apply those success elements.
To achieve the level of companies with top supply chains new business models are essential. Speed is getting more and more important and the competition switches from individual businesses to network competition. The keys to success in the battle of supply chains are visibility (to meet the real demand), shared information, great transparency, seamless processes and good collaboration.
To meet these criteria there are different challenges to overcome like joint strategy development alongside the supply chain, win-win thinking (both partners can benefit) and open communication. Conventional business models have changed a lot and Christopher points out seven major business transformations. First the trend is going from supplier-centric to customer-centric with the focus on responsiveness and agility rather than cost minimization and efficiency. Furthermore the 'demand pull' philosophy is implemented instead of simply pushing a product into the market without knowing if and how many products will be sold. Advanced visibility and shared information results in lower amounts of inventory. Fourth building relationships and customer retention are getting more important than solely focalizing volume and market share. Finding the best transportation route and optimizing the warehouse is still necessary today, but more than ever is the whole 'end-to-end' pipeline management becoming the focus. Additionally value-adding processes gain center stage and traditional, vertical organizations lose importance. The last significant change in business models can be found in the type of competition, from stand-alone to network rivalry.

As explained earlier Industry 4.0 enhances the customer-centric approach due to better visibility of the current needs. Pull systems with fewer inventories can be easier implemented due to the fact the actual demand is known way earlier (smart sensors, data analytics). Industry 4.0 simplifies also the co-operation and information sharing between companies (autonomous communication, data analytics). Optimizing transportation and value-adding processes can be best realized by simulating the whole value chain even from the customer to the supplier.

Future logistics managers need certain skills and education to achieve these previously named business transformations. A few of them are market and customer

insight, management of complexity and change, expertise in modern information technology, relationship management and understanding ‘cost-to-serve’ and time-based performance indicators. Additionally Christopher emphasizes the need for T-shaped skills profiles whereby the managers have in-depth expertise on one discipline but also cross-functional skills and the ability to connect each other.

12. Overcoming the barriers to supply chain integration

Traditional businesses will not be able to stay competitive due to high amounts of bureaucracy and hierarchical levels, unless they are able to restructure and focus on responsiveness. Defining the vision of the business (or mission statement) can serve as a guideline and should embody the core competencies (or the USP) of the enterprise. The mission statement is a good starting point, but there are serious problems in conventional businesses, which need to be solved in advance. If individual functions keep optimizing only their department (e.g. large batch quantities in the production) and ignore the rise in inventory afterwards, identifying the real demand is getting impossible, the visibility decreases and costs explode. Furthermore alternative cost systems like ‘activity-based costing’ (Chapter 3) need to be implemented in order to achieve transparency of the real costs of customers. Functional boundaries often hinder efficient end-to-end process management and therefore a smooth flow of information and materials through the logistics pipeline. Additionally conventional enterprises use sequential order processing system whereby a customer order is pushed from one department to the next. Allocating one person to a certain customer order who manages the whole process will enhance the overall service level significantly.

Christopher explains that the solution for these problems is a radical restructure from vertical, functional to horizontal, market-facing organizations. Horizontal organizations are organized around processes, flat and de-layered, built upon multi-functional teams and guided by performance metrics that are market-based. This type of organization focuses on processes like innovation, consumer development, customer management, supplier development or supply chain management rather than functions. Experience of various companies has shown that cross-functional teams with specialists from different functional areas led by integrators work best in process-based environments. Generating and fulfilling orders is still the number one process to keep the business running. For this reason a customer order management system with a market-driven requirements plan needs to be implemented to

recognize the current physical demand with advanced information systems. Christopher even mentions the idea to build several order fulfillment groups that have the knowledge to manage the whole process of converting an order into cash.

Due to advanced data analytics (or even AI) traditional companies have the chance to reduce the high amount of bureaucracy and slow information sharing. IT applications will be able to take over routine jobs and display the right information to the responsible people. In traditional companies with a lot of hierarchical levels the time it takes for information to reach from top to bottom or the other way around is way too long. Using smart sensors can furthermore support the team to focus on the core business due to the objects taking care of their problems on their own (e.g. one product is causing a congestion on the conveyer. Due to connected, smart sensors it is able to communicate with the 'emergency robot', which is then able to resolve the congestion.

As mentioned earlier a logistics-centered strategy is needed to stay competitive in the globalized market. Benchmarking, comparing parameters and processes in relation to competitors or other leaders, has become a widely used method to copy the best practices of leading competitors, provide motivation and stimulation for the professionals, reduces reluctance of operations to change and may identify a technological breakthrough. Finding the over-proportional influence factors ('key performance indicators' (KPI)) to success and failure and developing a 'Balanced Scoreboard' help to identify the crucial processes which need improvement and serve as a guidance.

13. Creating a sustainable supply chain

Sustainability is getting more and more important regarding every business sector and the society especially due to climate change. The most widely used definition is from the United Nations Brundtland Commission and states that

'Sustainability is meeting the needs of the present without compromising the ability of future generations to meet their own needs.'

For this reason the 'triple bottom line' was applied more frequently suggesting that every business decision impacts three key areas: planet (environment), people (society), profit (economy).

Supply chain managers also need to be aware of the greenhouse gases caused by industrial activities. Thus reducing the transport-intensity (or simply the distance traveled per product) of supply chains is a major goal in order to decrease the carbon footprint. Due to peak oil probably reached in this or the next decades and the growing demand due to centralized distribution, global sourcing, offshore manufacturing and just-in-time deliveries, the pressure to find alternatives constantly rises.
Supply chain decisions regarding the design, sourcing, making, delivering and returning not only impact the carbon footprint but the overall resource footprint of a company. Positive impacts can be achieved by following the '3Rs' (reduce, reuse, recycle) like reducing the packaging materials, avoiding waste during the production, minimizing transport intensity or managing the product end of-life (e.g. battery recycling).
Increased global trade, the lack of infrastructure capacity and just-in-time practices lead to congestions on motorways or bottlenecks on the railways/ at the port and therefore higher costs.

With a digital simulation of the supply chain it is possible to identify the transport-intensive processes and therefor reduce the carbon footprint. Means of transport with smart sensors even optimize the transport route on their own. Smart sensors on the product can help to support the product end of-life (e.g. giving the customer the information when and where to recycle f. ex. the battery).

14. The supply chain of the future

It is not possible to accurately anticipate what will happen in the future, but a few megatrends can help to identify a rough guideline. Particularly demographics and wealth redistribution will have a huge impact and supply chain networks may have to be reconfigured.
The Internet leads to multi-channel distribution often directly from the supplier to the customer. The visibility of real demand increases immensely, but keeping up the same customer experience and complementing each other regarding the inventory or distribution centers requires much effort.
Additionally the whole market situation changed from a 'seller's market' to a 'buyer's market' and from mass production to 'markets-of-one' with mass customization. Therefore a high amount of adaptability and agility is needed to stay competitiveness in times of virtual networks, information based and customer value oriented supply chains.

To achieve the structural flexibility to rapidly react on demand or supply fluctuations the most important factor is the willingness to co-operate with other enterprises. Merely with this mindset advanced visibility and information sharing, access to capacity (manufacturing, transport, etc.), access to knowledge and talent, inter-operability of processes and information systems and network orchestration can be achieved.

‘Doing more with less’ based on the 3R’s (reduce, reuse, recycle) and certain postponed customization with a focus on agility for supply and demand fluctuations will shape the future of supply chain decisions in the next decades. Information technology and other emerging technologies like rapid manufacturing will provide the basis for new business models and supply chains.

The future of Supply Chain Management and Industry 4.0

Theoretically the technology changes especially regarding the information technology are promising to keep the competitive advantage in western countries. Products with smart sensors can communicate with each other or with means of transportation (e.g. ‘still need to get a quality check, automated guided vehicle 5 pick me up’). With connected sensors in the machinery, products, containers, means of transport etc. it is even possible to create a real time simulation of the production and logistics (digital twin). The reaction time on demand changes or problems is therefor nearly zero or known before they even occur. With advanced data analytics it will be possible to detect trends earlier and use the data for forecasts. Furthermore with the development of artificial intelligence it is even possible that humans only need to intervene as necessary and most of the communication and operation is done autonomously. Nevertheless most of these innovations are emerging technologies currently in the testing phase. It is not predictable which technologies result in the biggest return on investment. Additionally the costs are high and mostly technical institutes or very big companies can only afford the research. Smaller companies may often use the traditional technology, because they are not able to afford a false investment.

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