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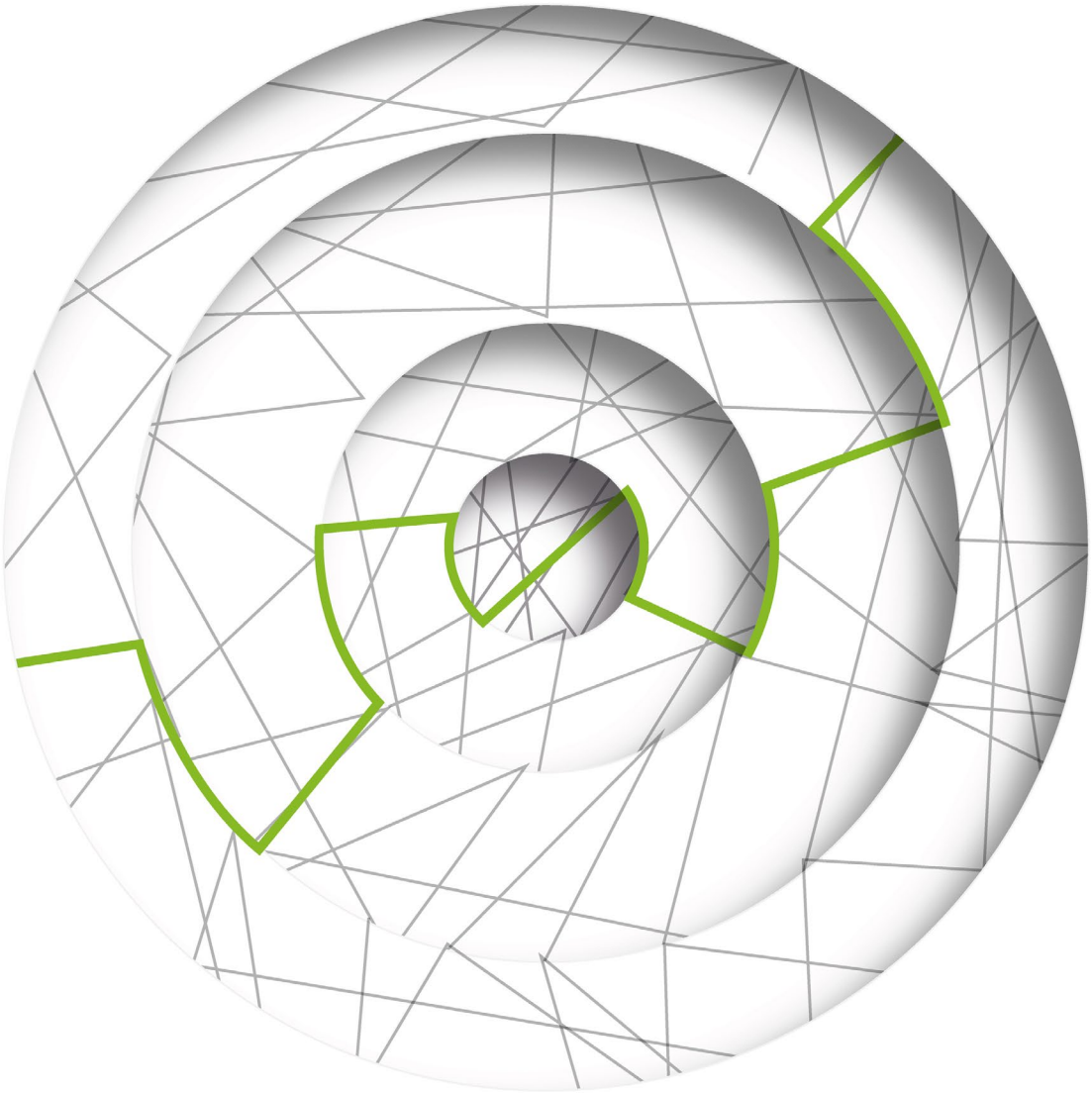


Resilient Spare Parts Management

What companies (can) do to mitigate risk in their Aftersales Supply Chains

The importance of continuous spare parts supply in manufacturing industries

In the past years, the role of after sales services has become increasingly prominent as both revenue and profit driver, especially in the manufacturing industry.

Buying decisions for machines are no longer taken merely based on design and engineering criteria, but rather on the question, 'How will you as my OEM (Original Equipment Manufacturer) support my business with the services provided, ensuring performance, efficiency and productivity of my machine?' Customers today are looking for life-time support and services – and when it comes to latter, spare parts supply plays a crucial role. Among others, factors that count most are obsolescence, availability and average speed of delivery as the break-down of a machine not only creates cost for recovery, but in many cases also entails a loss of revenue and a potential threat to the OEM's image and trust towards him. Deloitte has carried out a survey[1] for the automotive industry that shows the main barriers for excellence in spare parts related supply chain management.

Many customers may be reluctant to maintain a comprehensive spare part inventory because they fear that stocking assets like spares is counterintuitive when trying to effectively control operating costs. Even from a preventative or predictive maintenance strategy position, they depend on the OEM as their provider and partner in helping them ensure their seamlessly ongoing operations at the very point of disruption.

Thus, the professionalism in resolving incident-related issues, ensuring scheduled machine maintenance operations and keeping up a stable and reliable spare parts supply chain is one of the keys to gain and retain customers and a main pillar for business success.

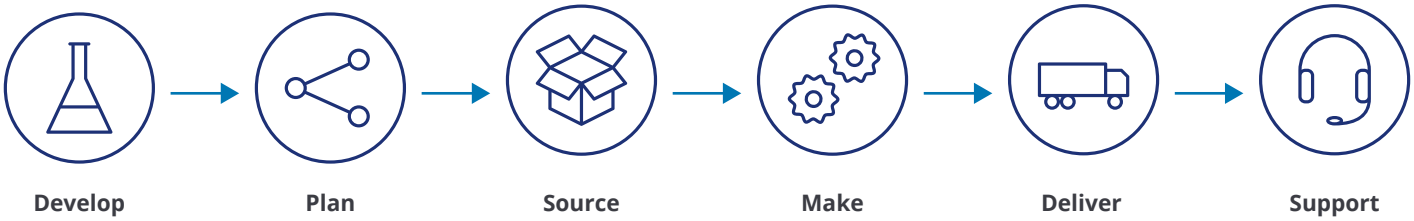
An OEM may ask himself: How can I ensure a seamless and trustworthy supply of spare parts and services to my customers? How can I mitigate risk?

Typical risks that can affect the stability of supply chains

The complexity of today's supply chains is susceptible to different types of errors. In order to optimize inventory cost and allow for greater freedom in planning, companies establish a make-to-order or even an engineer-to-order manufacturing environment and follow a just-in-time (JIT) or a just-in-sequence (JIS) production system philosophy – also applicable to the area of spare parts management. A disruption of material flow in the JIT/JIS chain has a major and often immediate, unbuffered impact on subsequent production or consumption points: shortage of semi-finished goods, standstill of production lines, lack of goods. It is not only the complexity of this process chain, but also the ecosystem of suppliers, production and storage facilities, transportation companies, subcontractors and operators and other actors in their respective geography that needs to be managed in day-to-day business and balanced against potential external threats.

Moreover, especially in spare parts related supply chains, speed and responsiveness to customer demand is crucial. Other than in a manufacturing environment – where there is a production planning, an often quite solid forecast based on historical values and experience: spare parts are mostly required due to unforeseen circumstances like machine break-downs and other incidents leading to a business stop. A single part may be the decisive factor whether a power station supplies a region with energy or a lung ventilator is operative or not. Building a resilient supply chain not only supports its stability, but also helps to make it more powerful.

Fig. 1 – Basic Traditional Spare Parts Supply Chain



Source: Monitor Deloitte

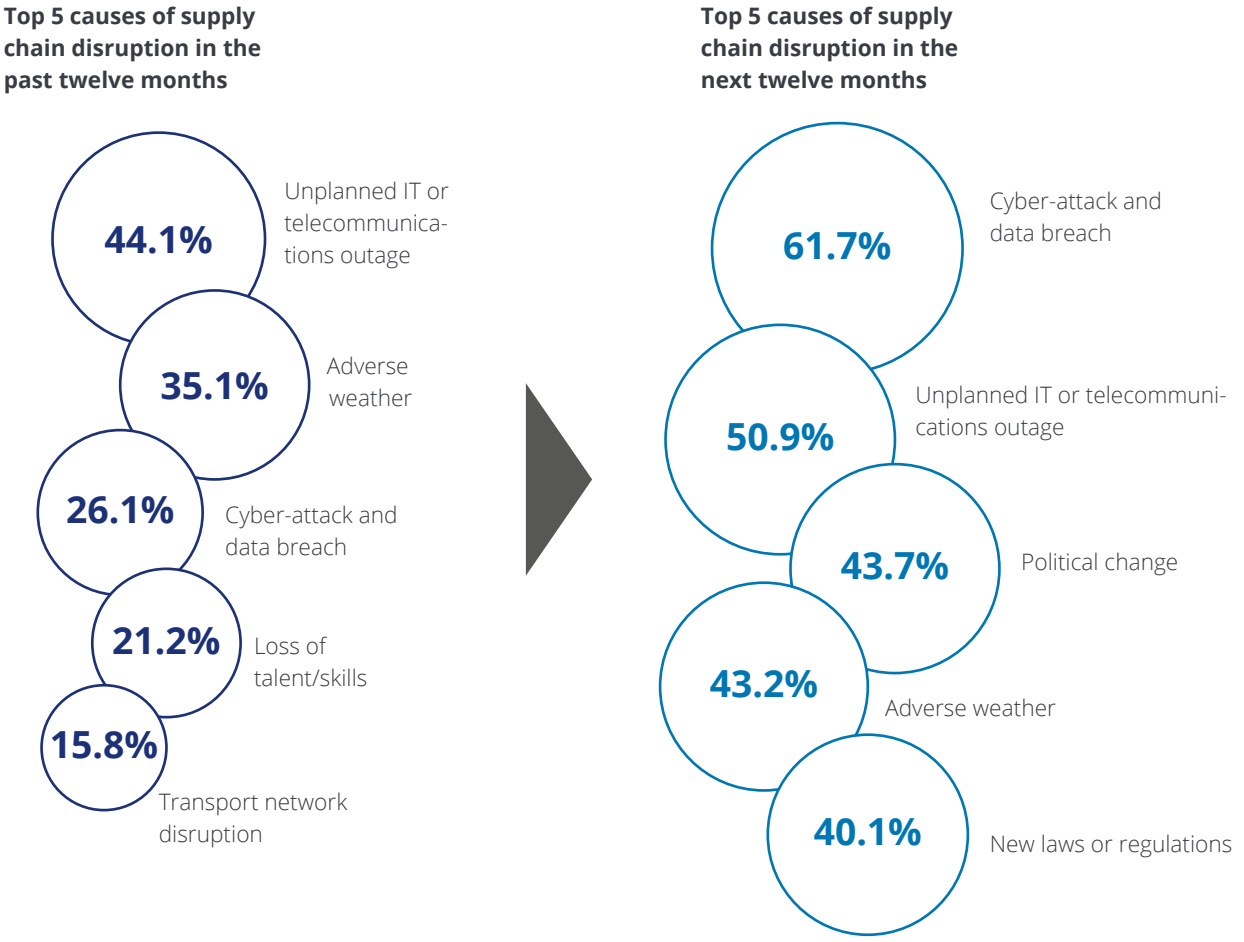
In order to optimize the supply chain of spare parts and immunize against potential threats and disruptions to the largest possible extend, a dual strategy should be pursued:

a) Risk analysis: identify (and continuously monitor) weaknesses in the supply chain by anticipating possible risks and their business impact, and refine the design of the supply chain accordingly;
b) Risk mitigation: prepare mitigation measures ready to deploy in the event of an incident to minimize the business impact of the disturbance and ensure continuation of supply chain operations

Clearly, (a) aims at a change over time, while (b) targets on immediate remedies to overcome a crisis.

In their 2019 report[2] , the Business Continuity Institute (BCI) provides an overview on the main causes of supply chain disruptions reported by 352 organizations in 65 countries and various sectors:

Fig. 2 – Top 5 Causes for Supply Chain Disruption



Source: BCI 2019/Monitor Deloitte

Undeniably, in the 2020 report the SARS-CoV-2 pandemic is likely to have a major impact on top 5 causes for both recent and upcoming months.

But what do these and other risks really mean for supply chain operations? The different fields of risks arising from incidents and conditions should be translated into tangible business impact:

Tab. 1 – Exemplary, non-comprehensive incident-impact-analysis

Risk: Incident or Condition	Business Impact
IT or telecommunications breakdown, cyber-attack, data loss or corruption	• Compromised supplier and customer (master and transactional) data • Loss of visibility and control over supply chain operations • Temporary breakdown and limitation of communication and business transactions • Cyber extortion (and consequential financial and business confidence related implications) • Temporary breakdown of business activities
Slowing-down or break-down of cross-border traffic	• Delay in production, production downtimes, loss of production • Delay/downtime/loss in service delivery (parts, technicians) • Mid to long-term changes in international movement of goods • Increase in transportation cost
Economic sanctions/embargo/ban/ boycott/halt in trading	• Production downtimes, loss of production • Loss of service operations (parts, technicians) • Long-term loss of business relationships (both suppliers and customers) • Increase in costs and prices; financial losses • Break-down of material flows
Regulatory controls, trade limitations, trade war	• Decrease or delay in production/service delivery • Re-design of production/service network layout • Increase in costs and prices • Change in production/warehousing/distribution footprint • Change in dealer network • Change in material sourcing • Change in supplier/distributor selection
Epidemic or pandemic diseases (SARS-CoV-2, Ebola, ...)	• Temporary breakdown of business activities • Delay in production, production downtimes, loss of production • Delay/downtime in service delivery (parts, technicians) • Loss of talent • Slow-down or break-down of material flows • Increase in costs and prices • Shortages in supplies
Terrorist attacks (and governmental counter measures)	• Temporary breakdown of business activities • Delay in production, production downtimes, loss of production • Increase in costs and prices • Temporary breakdown and limitation of communication and business transactions • Slow-down or break-down of material flows

Of course, this list is not comprehensive, and it is not possible to cover all eventualities. Nevertheless, it is important to identify the impacts a company, and, in consequence, its customers would suffer from most common threats, and to address those major effects with high priority. The risk analysis should cover the following aspects:

- What is the nature of the risk, where does it come from?
- What is the effect of the risk, its business impact?
- Which area of the OEMs or its customers business will be affected, and how long will the effect last?
- What are the costs or financial losses related to it?
- How big is the likelihood that the risk will occur?
- What are mitigation measures?

The product of likelihood, cost, and effect duration in context of the affected area of business provides an indication of the priority the respected risk should be dealt with. Mitigation measures should be developed accordingly. They can be reactive, i.e. they apply once the risk has occurred and aim to reduce the adverse effects on business, or they are preventative, aiming to minimize the probability of occurrence.

For supply chain management that means to analyze the supply chain end-to-end and to design it in a way that the likelihood of risks is minimized at best, and countermeasures are applied in a straightforward way.

What would that design look like?

Characteristics of a stable and sound supply chain management Set-up

There is no common recipe to waterproof spare parts supply chains to any kind of risks. Yet certain principles and methodologies, business best-practices and learnings from experience can be utilized to design a supply chain as solid and protective against risks as possible.

A resilient supply chain has the capacity to deal with changes, the ability to create new connections, and the presence of learning, collaboration, spare capacity and flexibility.

Over the past years, we have identified several areas of the spare part supply chain that turned out to be vulnerable to risks and therefore should be accounted for with primary focus.

Supply Chain Contingency

- Understand demand and supply side shocks/identify vulnerabilities
- Identify vulnerabilities and map critical features
- Develop contingency plans for operational disruption
- Develop inventory strategies to buffer volatility and risk

Supplier Network

- Diversify the number and geographies of suppliers
- Make parts production flexible or leverage additive manufacturing
- Consider re-configuring the distribution routing and service providers network

Warehouse Footprint

- Establish a multi-tier structure covering geographies (central warehouse(s), regional hubs, local storages), use balanced levels of different material, apply varying material flows
- Leverage decoupling points
- Balance advantages (e.g. increased availability) and disadvantages (e.g. cost for safety stock)

Transportation

- Establish Contract Management: SLAs in place corresponding to delivery demands; provider agreements allowing for flexible and cost-optimized charges
- Use diversity of transportation providers for diverse transportation needs
- Enter into trustful partnership with provider, grant high transparency on logistics needs, and permit to cover volatile business volumes

Material Categories

- Differentiate spare parts according to their strategic importance into categories
- Identify risks for supply disruption for each category and provide backup alternatives
- Ensure availability of critical, core competency materials

Collaboration

- Collaborate with key suppliers and customers to synchronize operations to priorities within constraints
- Deploy an extended network beyond tier 1 suppliers
- Determine levels of collaborative intensity

Supply Chain Finance

- Balance inventory with cash flow through agile execution
- Monitor inventory cost (acquisition cost, landed cost, carrying cost, ...) vs. cost of backorder, lost sales, or lost customers
- Continuously manage supplier contracts and evaluate cost vs. operations needs and performance

Intelligent Monitoring

- Invest in supply chain visibility: Establish control towers to predict, sense and prescribe risk responses with a connected ecosystem (machines, suppliers, customers (demand), ...)
- Scale to automated Digital Supply Network (DSN) solutions to improve end-to-end visibility, synchronization, optimization, and agility
- Transform the supply chain from a rigid physical system into dynamic cyber-physical SC and mitigate ripple effects
- Plan for resilience by making use of new disruptive technologies to increase flexibility and entertain switchover alternatives

In the following sections we will discuss each of these areas in more detail.

Steps towards resilience of spare parts management and supply chain

In the following chapter, we will have a closer look at the levers for a resilient spare part supply chain. As stated before, there is no common recipe. However, if only one of the above-mentioned areas is addressed, mitigation measures or resilience will only be reactive and fail to prevent customer service delivery disruptions in the future. To provide a broader perspective, we are outlining levers and examples both up- and downstream along the parts supply chain.

Supply Chain Contingency

As outlined before, it is elementary to identify and understand possible risks for supply chain disruptions in order to control the exposure to risk or reduce its negative impact on the stability and performance of the supply chain. To do so, the entire supply chain has to be mapped, and interdependencies between the different elements of it need to be fully understood. Potential failure points along the supply chain must be marked, subsequently evaluated, and critical risks need to be addressed by prioritizing funds and developing adequate measures to lessen the risk probability.

A basic prerequisite to manage the supplier landscape is to map the supply chain as a value stream and understand principal material flows, stock, stocking locations and organizations involved in order to identify critical features (e.g. capacity margins, competition for resources, few suppliers for bottleneck components or mono-sourcing) as well associated risks along the chain.

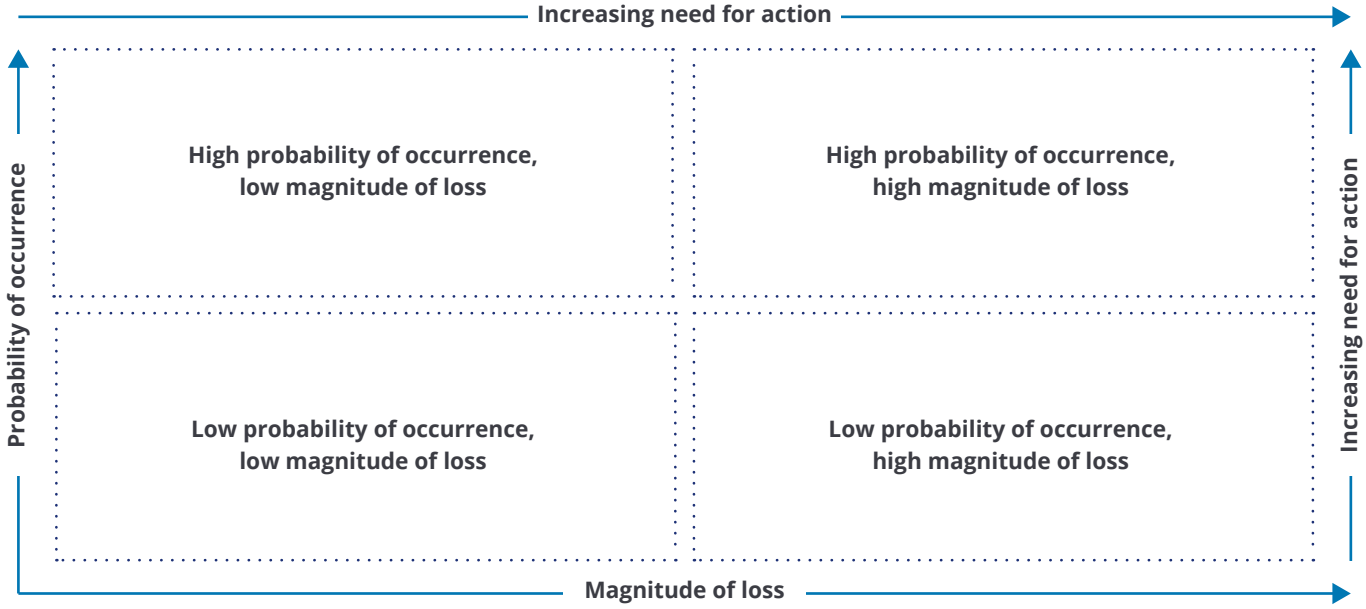
It is important to balance efforts and budget on the one hand, and the necessity of countermeasures on the other hand. Not each and every risk has to be mitigated, either because the likelihood of occurrence is low, or the negative business impact can be neglected. When it comes to spare parts, organizations range from a risk-tolerant to a risk-averse orientation, depending on criticality, particularity and overall availability of (individual) parts or distinct material groups. A contingency plan needs to take groups with the highest risk level into focus, develop risk responses, and allocate budget accordingly.

During the 2020 Coronavirus pandemic outbreak, RATIONAL, a leading German manufacturer of cooking appliances for large and commercial kitchens, faced the challenge of securing delivery capabilities for some of their spare parts sourced from China and Italy – countries that were heavily affected by the pandemic. As many of RATIONAL's parts are drawing parts that cannot be easily substituted or sourced elsewhere, RATIONAL followed a mitigation plan based on several pillars:

- Ensure the availability of spare parts in question at an early stage through increased central inventory volumes – balancing probable near-future demand with inventory carrying costs
- Close information loop and cooperation with suppliers regarding their delivery capabilities and organizational situation
- Identification of alternative suppliers able to manufacture according to drawings and specification as a fall-back interim solution

Fig. 3 – Risk levels

Risk level: Likelihood of Occurrence × Magnitude of Loss (Cost & Duration)



Risk responses can typically range from preventative measures, i.e. measures prepared and deployed before a certain risk or type of risk occurs (aiming to reduce probability or severity of the risk), to contingent actions, i.e. responses that are applied during or after a harmful risk event (aiming to minimize monetary, physical, or reputational damage). Also, methods how risk responses work can follow different approaches. The table below illustrates this.

Fig. 4 – Risk Responses

Response type	**+** preventative **–** contingent	**–** preventative **+** contingent	**+/–** preventative **+** contingent	**+** preventative **+/–** contingent
Methode	**Accept** **Take no action, or unable to create/ establish a plan**	**Transfer** **Insurance, or contractual transfer to a supply chain partner**	**Mitigate** **Preventative measures to reduce likelihood or impact of risks**	**Avoid** **Changing a plan to eliminate risk or its impact**
Example	**Risk** Breakdown of the entire supply chain organization **Response** Ø (subsequently rebuild organization)	**Risk** Loss of warehouse, delivery, ... **Response** Reimbursement of insurance/ SC partner	**Risk** Running out of inventory for highly critical spare parts **Response** Sufficient safety stock	**Risk** International transportati-on on hold **Response** Adequate transportation network and delivery partners in place

+ has effect on /– does not have effect on respective response type

Contingency planning should be part of a company's supply chain strategy, and monitoring the supply chain network, the evaluation of its exposure to risk, and review of risk responses should be part of an organization's periodic business routine. Main tactical pillars are:

- Prepare contingency plans and keep them updated
- Don't rely only on extra stores of inventory – there can never be sufficient spare parts to cover all possible eventualities. Also think about processes and variable sourcing
- Learn from best practices and experience others made, and apply learnings
- Pay special attention to the stability of information flows. Involve suppliers, customers and partners in the contingency planning and make sure they are involved
- Test plans, train both employees and partners to understand them, and implement them

Supplier Network

Diversify the supply chain

Knowing and orchestrating the supply chain network is one of the key features for resilience: focus is the organization itself, but also partners downstream and upstream. Key is to identify and manage constraints on either the material (e.g. shortage in raw material, single supplier) or capacity (e.g. the slowest step, no reserved transport or supplier production capacity). Of course, an inventory strategy to buffer before and/or after the constraint can help. Apart from buffering, it is about diversifying the supply chain.

Diversify sources and geographies

Assuming the OEM is focusing on a single key supplier for its components today, driven by the OE (Original Equipment) business. Common practice, especially in the automotive industry, is to concentrate the supply of specific components on just one supplier to bundle volumes and maximize economies of scale. The downside of this mono-sourcing is, however, a high risk exposure to supply chain disruptions.

A manufacturer of bending machines, for example, has a single supplier for bending tools and primarily a contractual agreement for the original equipment. When re-ordering tools, customers often face long lead times due to stock-outs as the manufacturer is one of multiple customers in the eyes of the tools provider.

A guiding principle for after sales is to source key components from multiple suppliers to reduce the reliance on one supplier – wherever possible. Activating alternative sources for critical items (see chapter Material Categories) to secure additional critical stock or capacity is a re-configuration of the supply chain that should be taken into consideration.

Apart from single sourcing, suppliers are often geographically concentrated, e.g. close to the plant or in a specific region of the world. In light of a more resilient supply chain, especially in the after sales, focus on a geographical spot should be revised: if suppliers do concentrate regionally in one area, alternative suppliers in other regions of the world should be identified to prevent regional supply chain outages. If the main supplier is based in China, one might want to orientate also towards Mexico, Brazil, Chile or India as an example (or vice versa). Additionally, the OEM's installed base coverage can also serve as an indication for regional alignment. One should keep in mind that often tier 1 suppliers heavily depend on their material inputs. Accordingly, the evaluation of alternative inbound logistics options and secure capacity by and beyond tier 1 suppliers is advisable.

Taking a manufacturer of commercial, mining and agricultural vehicles as an example; in the after sales business, having two to three suppliers per product and region is set as a standard. Though around 70 percent of parts are manufactured in-house, backup sources per region are a must. When parts supply and delivery are disrupted in one area, e.g. closed factories in China due to COVID-19, the firm leverages its alternative supply base and is still able to deliver to customers.[3]

Overall, we are not recommending replacing suppliers or logistics providers, but rather prioritize what parts will be produced or sourced in the event of raw and direct material inventory shortages, especially when a component is both used in after sales and production. Often companies treat their parts business poorly leaving customers to turn to alternate sources in the event of difficulties in parts delivery.

Diversify the making-of – manufacturing options

An additional opportunity within an OEM's ecosystem may be to install an Additive Manufacturing (AM) hub and/or establish a decentralized setup. AM can be one of the remedies against unpredictability and obsolescence. Obviously, the industrial applicability of additive manufacturing is still limited as the technology has several restrictions where to be applied efficiently. Nevertheless, the technology is still evolving rapidly and the application scope – where its usage is possible from an engineering perspective and simultaneously efficient from a financial view – is growing. Siemens Mobility Services, for example, has started to invest into AM years ago. Today, it is an undebatable element of its promise to their customers as Torsten Wehrkamp, Vice President Spare Part Services Siemens Mobility states: "Identified in 10 seconds, ordered in 3 minutes and delivered in 24 hours"). This is only possible by Additive Manufacturing: parts, whenever possible, will be "printed" in AM centers around the globe.

With this consistent vision and global implementation, Siemens Mobility is a benchmark in the manufacturing industry.

Accordingly, AM can be used to reduce the need for risk mitigation for inventory in the parts supply chain and replace missing materials and components. This will ultimately enhance the control over inventories and alleviate capacity reservations at the backup suppliers. Switching to AM provides supply chain flexibility advantages not only for reduced inventory, but also for production, shorter lead times and individualization.[4]

AM can be of interest especially when concerning spare parts for ageing assets. Typically, suppliers have gone out of business, request long lead times or a minimum order quantity. When embedding additive manufacturing into the supply chain, bottlenecks in supply are reduced while service levels are kept.

Make the production flexible

If spare parts are being or can be produced in-house, contingency plans can look into re-scheduling and balancing the original

equipment and after sales business. Production schedules should be refined based on inventory on-hand, demand changes and production capacity, while simultaneously components that might put most important products at risk of stock-outs should be stockpiled (see section Material Categories). Taking ZF during the COVID-19 lock down in Germany as an example, the aftermarket business department reserved one day capacity in the production schedule per week (if needed) to manufacture own spare parts, with breathing capacity of two days every two weeks. Whereas – primarily in the automotive industry – warehousing utilization has significantly declined in line with dropping new vehicle sales, after sales service parts warehouses are running at nearly full capacity, especially in the off-highway industry (until last week in March, since then a growing drop in demand has shown up, but different per country and customer).[5] "After Sales has received recognition as being system relevant worldwide" states Helmut Ernst, Executive Vice President ZF Aftermarket.

One of the most recent examples for a flexible practice of production site usage is a global leader in consumer electronics, geographically moving its supply chain incrementally from China towards Taiwan. Otherwise, the tech company would have gone out of components by the end of the same month. At the same time, the company is working together with its Chinese suppliers to resolve issues derived from the COVID-19 outbreak.[6]

Plans to mobilize and re-routing production might be advantageous to handle emergencies.[7]

"Spare parts are the engine in the aftermarket. In the interest of your customers you want to make sure that it does not sputter."

Oliver Bendig,
German After Sales & Industrial Manufacturing Lead
at Monitor Deloitte

Warehouse Footprint

As more and more installed base is located outside of an OEM's home region and a growing share of spare parts are manufactured abroad by partners across all continents, the need to globalize the supply chain has increased continuously.

Typically, a network of storage locations in various regions is established according to the prevalent distribution areas of customers of the OEM. While those networks normally grow "historically" with the increasing number of clients, it is worthwhile to review this structure regularly. The lead question is, does the existing network allow for supplying my customers within the agreed service levels? More specifically:

- Do I have sufficient stocking locations to supply my customers in time and quantity?
- Do I have as few as possible stocking locations in order to optimize my inventory carrying cost?

In order to find answers to these questions, most companies establish an echelon warehousing structure where one or only a few central warehouse(s) supply Regional Distribution Centers (RDCs) that either deliver (rare or costly) parts directly to customers or replenish local warehouses on the next tier. The same structure would be used for the reverse flow of parts (repair or refurbishment). The general philosophy is to store certain groups of spare parts only in one location per region and serve the entire region out of that one central/regional warehouse while other material groups – high runners/AX materials – may be on stock in each location to facilitate better availability.

Some companies have been able to quickly secure additional "strategic stock" from alternate suppliers in anticipation of key supplier disruption. Developing relationships with alternative suppliers can also provide the necessary breathing space.

These measures can create quality problems and add costs, but a buffer is necessary to provide an immediate response to disruption.[8]

Many manufacturers have a dealer network in place – dealers not only selling their products, but also providing services and storing, using and selling spare parts. Mostly, the inventories of those dealers are a black box for manufacturers as these do not have a live view on the inventories – nor do they analyze historical data what has been sold and replenished. Deploying a digital Managed Dealer Inventory (MDI) is a solution that allows organizations to make those decentral stocks visible and helps to automatically create reordering/replenishment suggestions. An MDI facilitates a closer relationship with the partner network as it makes it easier for them to accelerate the order management process, avoid forecasting failures and increase spare parts revenues through availability – not only in crisis situations.

Securing parts distribution and jointly working with dealers to generate solutions is key during supply chain disruptions. In the agriculture industry, dealer networks supply farmers with parts. CLAAS, an agriculture OEM, is working closely with their dealers to minimize parts cut-offs and make up for equipment production during the COVID-19 outbreak. As an OEM, CLAAS relies on its key suppliers for axis, tires, engine and hydraulic components. Especially sub-suppliers in Italy and France faced difficulties in production and delivery, what ultimately lead to a reduced production for suppliers. Nevertheless, CLAAS supplied critical parts with priority. Dealers benefit from continuous supply by the new high-rack storage in Hamm, Germany, and a network of six decentral warehouses across Europe.[9]

In the past, inventory levels have been optimized year over year and more and more sophisticated algorithms have been applied to optimize stock levels in order to balance availability and lowest possible net working capital – in recent years though, they have been tuned to a historical low and are not meeting the increased variability for demand and supply[10]. A decades-long focus on supply chain optimization to minimize costs, reduce inventories, and drive up asset utilization has removed buffers and flexibility to absorb delays and disruptions. This may still work in a process-line production when waiting times for a new car of six months and more have become normal and automotive manufacturers can inform their suppliers and sub-suppliers three months in advance on exactly which day a specific car is planned for production. And in case the delivery of the new car that one had to wait for six months and longer anyway is postponed by another two weeks because a component could not be produced or was delayed from Asia to the production facility in the U.S., it will typically not have a dramatic impact as long as one is informed ahead of times. However, imagine a critical component of a surgery equipment in an emergency room is not on stock in the single European central warehouse of the manufacturer; as a result, a surgery may not be pursued, and a patient's life may be endangered. Critical infrastructure like water, energy or telecommunication could fail due to a cut in the global supply chain of one critical component – those situations will impact all of our lives.

The necessity to set safety stock parameters properly is obvious. Crisis situations show that companies need to consider how they can refine their inventory strategies to mitigate two risks: running out of stock on one side, and sitting on inventories not in demand on the other side.

In lack of a golden rule, there are several points that should be taken into considerations:

- How many of an OEM's customers are dependent on its parts – i.e., what happens if their production is down? Where are those customers located? Does the OEM know their demand, and does he forecast accordingly?
- What is the cost of safety stock? What is the cost of failure?
- Are the decoupling points with suppliers and customers properly set?
- How does the warehouse footprint match the need of clients? What does the material flow look like – to customers, but also between stocking locations?
- How much redundant stock does exists?
- Does the OEM have an insight into the dealers' inventories?

Transportation

Another limiting factor in shipping parts to the customer can be the logistics as it is prone to disruptions. Similar to the ideas above about diversifying suppliers and geographies, overall capacities, number and locations of transportation hubs and routes should be checked in order to establish a flexible and profitable logistics network.

Diversification of the logistics providers network

When looking at distribution structures, the installed base should set the pace in terms of regional coverage, speed and frequency here.

Alternative outbound logistics and service provider options should be evaluated, and by closely working together with partners needed capacities should be secured. Of course, having a full-service provider to manage warehousing, packaging and distribution has a coordination advantage. Besides, there is a possibility to place buffer stocks as a decoupling point. However, upsides should be outweighed as they also bear risks in disruptions.

Transportation options need to be analyzed per region and matched with local customer requirements and provider coverage. In case of closely working with one selected logistics provider, a clear understanding of shipment capacities, service level agreements and dynamic capacity to manage situations are vital.

For their land-bound trans-European service parts business, PENTAX MEDICAL perceived a significant delay in deliveries in the beginning of 2020: At the dawn of the Coronavirus outbreak, cross-border traffic had come to a stop due to massive controls and an increase of travelling repatriates. Together with their carrier, PENTAX MEDICAL decided to switch to delivery via airfreight. Obviously, transportation costs were higher, but PENTAX thus made sure that critical components met required delivery targets.

It was essential, by the way, that their carrier used dedicated cargo aircrafts – and not passenger planes as private air traffic had come to a stop.

Avoid self-made bottlenecks in express delivery

There are two phenomena we frequently face: Lack in visibility of on time delivery (OTD) at the customers' site and lack in service levels within the firm and towards its shipping companies.

Firstly, the parts "out of sight" are "out of mind" with leaving the platform at the OEM's goods issue. Companies do not adequately track the transportation providers' adherence to on time delivery. Parts might have left the warehouse on time, but ultimately reach the customer too late as the shipping company is defining distribution according to its schedule. There is a need to collaborate more with logistics providers for dynamic capacity in terms of bottlenecks and aligning on time delivery on the last mile.

Secondly, too often there is a lack in differentiation of service levels both in the warehouse and during the shipping. In many sectors of the machinery industry an emergency rate of 50 percent + of spare parts orders is daily business. Emergency orders or express delivery though, typically means that spare parts are delivered immediately or overnight for example from the Central warehouse in Northern Germany to the equipment in the Northern part of Spain. Often ordering a spare part as an emergency case is not necessary, but customers or service technicians got used to it. They are not aware of the resulting cost and process complexity and simply hit the button "Emergency Delivery" in the order application. Right incentives should be in place here to shift towards replenishment orders with standard lead times of e.g. 2-4 days instead of 24h delivery. When defining service levels correctly, one might want to align priorities with material categories accordingly (see chapter Material Categories).

Alternate transportation routes and modes

Some companies are looking into diversifying their routes from China to Europe, for example (e.g. rail to the port of Rotterdam and then sea freight to North America) and moving away from a "one-hub-policy" towards alternative hubs in other regions. They are able to quickly adjust their distribution network and delivery speed to alternative regional distribution centers or depots or transportation providers. In any case, having an exception handling in some rare cases like a charter flight from South America to Europe might be economically justified.

Turning to disruptions at the last mile, one should check for alternative delivery options. For example, when the logistics provider is at full capacity or blocked, routing the parts delivery via local couriers, own employees or taxi drivers might be an idea. To illustrate this, a manufacturer of building technology in Sao Paolo switched to "go fleet-less" in metropolitan areas, where parking is impossible. A service technician carries a trolley with his core tools using the underground or ride-hailing companies to shuttle from one equipment to the next. Spare parts are delivered on demand

directly to the equipment by a courier – at the time and point when the technicians need them to conduct the maintenance task. Today the company considers rolling out this model to all metropolitan areas globally.

Outsource value-added services on demand

When a region is being locked down, as seen for example during the COVID-19 pandemic, and own warehouses and staff are not able to perform their work anymore, outsourcing assembly, packaging, warehousing and shipping to a third party logistics provider in an alternative region should be evaluated. An up-to-date overview and backup plans should be in place to be able to react swiftly.

> "The growing demand of services in manufacturing industries requires versatile and effective organizations."
>
> Thomas M. Döbler,
> German Energy, Resources & Industrials Lead

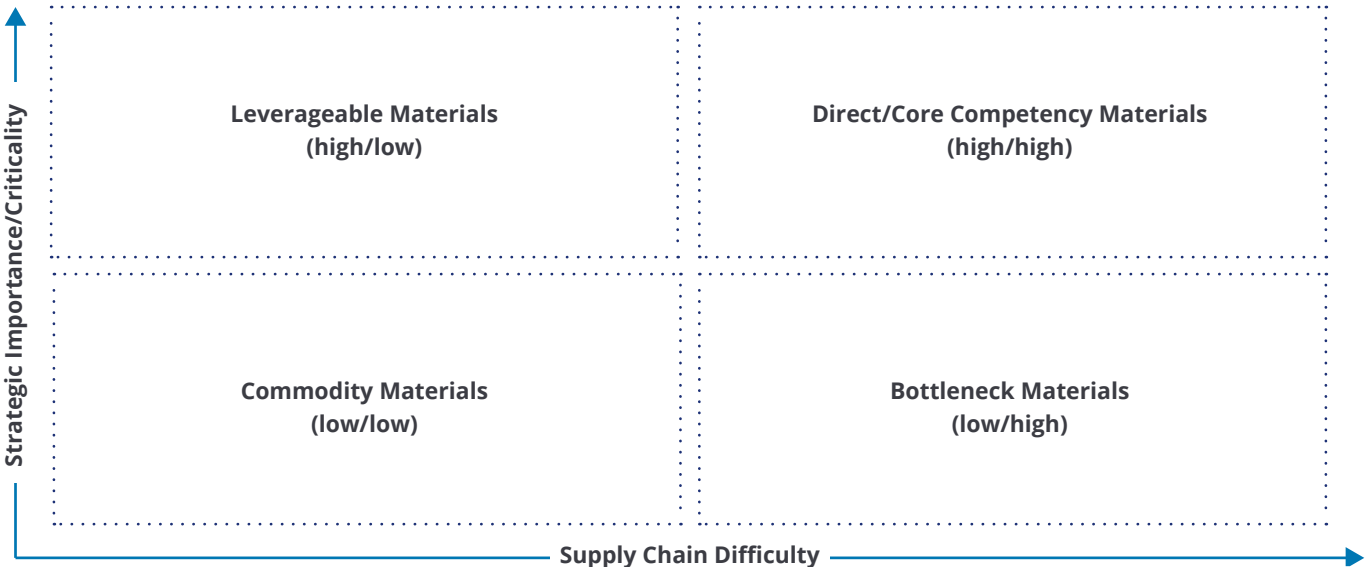
Material Categories

The basic idea behind material categorization is to prioritize inventories by identifying those spare parts most vulnerable to disruption and/or critical to supply. A sample categorization could be built upon two criteria:

- Materials with high strategic importance for an OEM or his customers, or high criticality
- Materials with high supply chain difficulty (i.e. risk of supply disruption, e.g. difficult to produce, difficult to store, high demand, rare, ...)

The resulting matrix would allow for a categorization of materials into four groups, see Fig. 5.

Fig. 5 – Simple Material Categorization



Clustering a spare parts portfolio according to the criticality of parts is a basic step to know where to focus resilience efforts upon. There are two perspectives to be synchronized: the customer's view on the criticality of the part, and the OEM's view as a parts provider on the risk exposure of supply production. Therefore, combining strategic importance/criticality and supply chain difficulty might assess the entire parts portfolio. A good starting point is to define part groups/families and further move down to SKU level. An ABC/XYZ matrix* can be taken as an example, and the above segmentation criteria can be applied to identify bottleneck materials vs. commodity materials, backup materials, and the core materials. The prioritization of the inventory and supply tactics for the core materials should be conducted, and supply chain risks for the backup and core materials need to be investigated.

Also, think about the differentiation between "production part" and "spare part": most of the time the exact same piece of material, yet a different designated use. On the one hand, one does not want to put new equipment business at risk to delay production or delivery. Yet at the same time the risk of downtime of the customer's production process due to stock-outs of most important spare parts from is high. Keep in mind: Sales sells the first equipment; service sells any following one.

For core competency material, stocking rules should be set in a way that inventories allow for sufficient supplies even during crisis situations. Especially in times of scarce supply, allocation of available inventory to either a first come first serve demand, fair share approach or differentiated view on top customers or materials[11] could be a viable rule. Original equipment business and after sales business need to be balanced. Production schedules should be refined based on the inventory available, changing demand and what the OEM is capable to build, while at the same time ensuring that component parts are not used that put the most important products at risk of stock-out.

Nevertheless, rapid re-planning of production schedules may be necessary. During Fukushima for example, there was a shortage in supply for reverse cameras in the automotive industry. Accordingly, cars were built and sold with a dummy part. As soon as the material bottleneck was resolved, the service business was to retrofit the available parts. A solution for the car sales, however, a struggle for customer service.

If digital tools or – regular – organizational capabilities to support rapid re-planning are not at hand, a war room type of environment with selected supply chain experts, sales and service personnel may act as a short-term and interim solution.[12] In the long run, building a versatile organization with a clear process set-up and automated digital supply chain tools is inevitable.

* A matrix sorting material according to their stability of demand (and resulting inventory forecasting accuracy) and their value.

Collaboration

Moreover, stabilizing the supply side is one side of the medal. Production lines came to a stop when two suppliers cut off their deliveries as protest against a contract cancellation, fail to manage contractual relationships and identify sensitive materials in light of a pure cost-centered KPI system.[13] The parts shortfall led to severe consequences for one or the other automotive manufacturer: it not only disrupted production, but also send 28k+ workers to reduced hours.

Managing supplier relationships and proactively collaborating with both suppliers and customers to synchronize operations with constraints present can prevent a parts supply chain cut off/prevent disruptions beforehand.

Joining forces with key parts suppliers

First thing is to focus on tier 1 supplier risk, working with key suppliers to understand their ability to meet supply chain requirements and potential risks. Unlike in the automotive industry, where often 1:1 supplier-OEM relationships can be found, it is necessary to understand how a company will be treated in the event of disruptions when it is most likely one of many customers a machinery industry supplier might have. Given an inventory or capacity shortage, it is crucial to understand their ability to quickly reconfigure their supply chain to other locations.

Accordingly, close collaboration with key tier 1 part suppliers to get visibility to their inventory, production, purchasing and order fulfillment status is advisable, along with active communication, determination of the right level of collaboration intensity and the joint development of alternative plans. Shedding light into the OEM's and their supply chain vulnerabilities will save both in the future. In many cases suppliers might already have started to think about resilience, nearly 50 percent of suppliers claim to have business continuity plans in place to deal with supply chain disruptions.[14]

Collaboration helps to discover opportunities lying within the supply chain network, like establishing a stock pool for raw materials inventory, which is an approach that large companies in China used in the past.[15]

Creating awareness for resilience with partners

Turning to new or alternate suppliers, supply chain risk management should be put in place right at the beginning of the assessment by requiring a statement of supply chain resilience as relevant part of contractual conditions. Getting partners to create awareness for contingency plans, by providing a self-assessment, auditing supply chain vulnerability, etc., is good practice. If they haven't come up with plans for resilience yet, this might be a good opportunity to start and can also be used as a selling point or marketing with their other customers.[16]

Unboxing an extended supply network

However, tier 1 suppliers are not fully dependent on themselves. They could still have the capacity to manufacture, but lack subcomponents, e.g. the case from their suppliers, to finalize the assembly of the valve. Therefore, understanding what will affect the tier 1 supplier performance and transparency about the tier 2 supplier status are paramount.[17] To work with tier 1 partners to get as much visibility as possible and leverage digital capabilities to save time is crucial.

Given the example of an airplane manufacturer, that depends on its multi-tier supply network, managed to further increase its on time delivery (OTD) to customers backing upon a managed inventory program with its partners. If a component was missing, it often led to delayed delivery.[18] Due to the high value and critical nature of these parts, the complete chain got disrupted as production and delivery were stopped. To eliminate future risks of supply chain cut-offs, the OEM collaborated with multiple partner tiers on the complete order lifecycle, tracking planning schedules and a managed inventory program based on a shared risk-model. They invested into logistics visibility tools. Synchronizing the demand and supply information by sharing order, inventory and supply information across supply partners helped to minimize disruptions and heighten on time delivery.

It is important to collaborate with partners to orchestrate remedial actions across the combined network[19] and thus creating network resilience. One needs to keep in mind that not all of the suppliers might have the capabilities or resources to investigate and establish actionable plans. In this case an even closer work relationship with them and supporting them will pay off in the future.[20] After mapping out the critical features and identified SKUs beforehand, it is important to determine the suppliers of strategic importance and carefully choose the collaboration intensity.

Collaborate downstream

Apart from communicating with suppliers, customers should not be forgot about. As soon as shortages in inventory are likely, communication with key customers should be instantly commenced. The exploration into alternative supply options and work on equal footing to minimize losses is a measure that, besides keeping contractual obligations, will prevent losing customers. Nevertheless, screening the customer base for stability is inevitable. During a financial crisis for example, firms need to take a decision whether to trust customer orders and potentially investing in collaborating in a delayed payback in order to support key customers.

What is more, upstream is not the only way to secure additional capacity. In the agriculture industry, for example, the supply chain integrates dealers as partners. An OEM works closely with its largest parts distributor and the dealer network. Throughout the entire network, there is full transparency of inventory. If in one region dealers went out of stock regarding a single part, they

can see who else might have the item available. Besides, the OEM and distributor benefit from demand transparency and can optimize the assortment and spare parts planning as well as the supply.

Moving further downstream, collaboration with customers can also alleviate supply chain disruption. Given shortages in inventory or capacity of parts supply, pooling inventory of multiple customers can provide an opportunity, another is leveraging the stock at one customer site for a third-party customer. For example, due to a recent replenishment and high safety stock of customer A, there can be an arrangement with the OEM or a customer B to draw on the missing part from customer A. As an OEM, why not look into possibilities beyond the supplier network?

Consequently, making constraints and risks visible along the supply chain and collaborating with both suppliers and customers to synchronize operations with priorities helps to mitigate disruptions.

> "Industry 4.0 won't work without solid supply chains."
>
> Harald Proff,
> German Automotive Lead

Supply Chain Finance

Even during not extraordinary and exceptional times or situations, supply chain financial management is one of the most important disciplines. Ultimate goal is to balance adding value to customers by, in general, the ability to supply in time, and on the other side ensuring a company's positive cash flow and liquidity. Financial strength can be achieved e.g. by sharing administrative costs for shared activities in the supply chain with the partner, by sharing risk, or by limiting invests if firms in the collaboration network are willing to assume leadership in their core competencies.

But what are specific levers that can be pulled when facing a crisis?

Let's assume the following five basic conditions putting pressure on financial management in a spare parts supply chain:

- Stop or decrease of a customers' manufacturing capacities leads to an increase in the warehouse inventory levels/volatile demand of the customers for spare parts
- An OEM's manufacturing capacities (for spare parts) or those of his suppliers decrease or come to a halt (up to supplier insolvency)
- Warehouse stock regionally not available, or stockouts
- Transportation services do not conform to regular performance standards
- Personnel/staff in a company relevant for spare parts and/or supply chain operations not available

Measures to be prepared

In order to evaluate a situation properly, it is mandatory to have full visibility upstream and downstream in the supply chain. A stable and regularly performed demand management shows early indicators in consumption changes, even when forecasting in non-standard situations shows a lack of accuracy. The Sales and Operations Planning (S&OP) cycle provides relevant information and allows for application of adjustments at an early stage of business shifts. Further transparency can be gained by the installation of a Supply Chain Control Tower (see chapter Intelligent Monitoring) that allows for real-time information at the push of a button, facilitated through intelligent sensing and digitally driven requirements analyses. A Control Tower helps to improve forecast quality even and especially when extraordinary circumstances apply, and to segment data in order to identify first inefficiencies and cost leaks.

In difficult times, an OEM may be dependent on certain parts from his suppliers, as customers are dependent on certain parts from the OEM. To precisely know which parts are crucial for both the OEM as well as for his customers should be a regular task involving departments like Purchasing, R&D, Production, Logistics/Spare Parts Management and Service. Primary objective is to create a material segmentation exhibiting those material groups that are critical for operations (see chapter Material Categories) and thus should be kept on stock with a higher priority based on according stock rules (e.g., replenishment cycles, level of safety stock, bulk procurement, etc.). Fulfilling the market demand for these materials helps customers and also the OEM in supporting a steady revenue stream and keeping up the company's image as a trustful and reliable service partner. In respect to sourcing of these materials, it may be a future-proof strategy to partner-up with more than one supplier in case this one drops out. Another strategic way can be to enter into consignment stock options, or even engage in supplier financing.

From a financial perspective, the entire supply chain network can be segmented based on revenue streams. Regular demand and cost-to-serve analyses help to identify and describe the financial flows, accompanied by regular total landing cost sourcing analyses. These activities should be incorporated into the periodic S&OP sessions (see above).

When it comes to transportation, it is helpful to follow a multi-partner approach where each partner can play out its strengths in respect to different transportation routes and methods. Also, 3PL providers are bundling competencies and can offer a variety of professional services even beyond mere transportation, e.g. warehousing (to cover dynamic situations), customs clearance, harmonizing tariffs etc.

Last not least, a contingency plan should be put in place that covers organizational minimum requirements. When people are not available for whatever reason – from virus outbreak to short-time work – it is necessary to have a definition in place which functions in the supply chain are indispensable, and who can take these positions, otherwise expenses for inoperability will rise.

Measures during the crisis

During a crisis it is important to understand what is going on in the supply chain – upstream and downstream. It is mandatory to keep up communication to both suppliers and to customers. What will be the change in demand? Is the supply of the most critical parts secured? Some of the immediate, financially relevant measures to be taken into consideration are listed below:

- Adjustment of warehouse capacities according to the new situation.
- Lower inventory levels for material groups that are about to show a decrease in demand in order to save inventory carrying cost.
- Not hoarding materials one cannot sell.
- Increase of levels for material groups that are critical in order to respond to market requirements and thus stabilize

the revenue stream, at the same time avoidance of loopback effects that may endanger liquidity*.

- Check of transportation modalities. Ensuring that business and operational requirements do not outweigh transportation costs.

  During the Coronavirus outbreak, a company in the construction engineering sector decided not to switch to airfreight even though there was a backlog in empty containers for sea freight, and overland transport was obstructed. Reason: cost would have been too high.

- Even closer collaboration with suppliers, especially those critical parts are sourced from (see chapter Collaboration). How did the crisis impact them? Are they able to produce? Will they be able to deliver their product to the OEM, in time? Are they financially healthy?

  There are examples from companies that were supporting their suppliers in a financial way – for instance by prepaying invoices or deliberately shortening due dates for payment.

- Shortening of cash to cash cycles (reduction of cycle time). There are several ways to accomplish this, e.g. by turning over inventories faster, and asking customers to pay sooner (e.g. by offering them a discount).

Almost all of the immediate measures may require some preparation before the risk impacts hits business, so it is worthwhile to spend some time to waterproof the weakest elements in the supply chain upfront.

* Loopback effect means to produce too much in order to respond to market demand, yet revenues do not cover exceptional manufacturing expenses, and materials could be overproduced.

Intelligent Monitoring

Plan for resilience

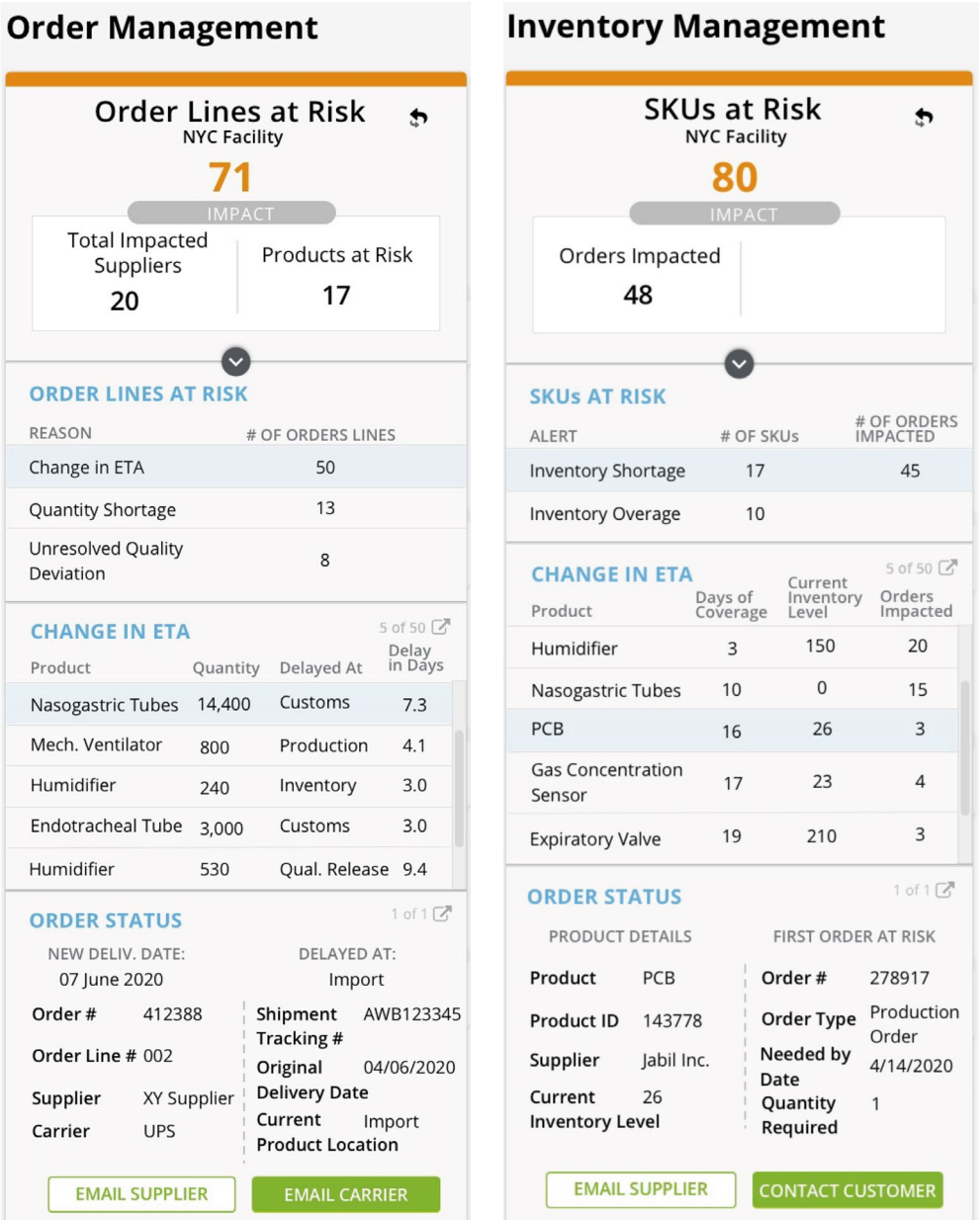
Traditionally, supply chains have been viewed in a linear way, where planning was paramount in a relatively "simple" world with low uncertainty. However, the past focus on minimizing costs and focusing on the supply chain within organizations is undergoing a paradigm shift: today, end-to-end supply chain risk management (E2E SCRM) spans physical supply chain functions and product risks across all supply chain domains and time horizons from strategic down to operational, taking spare parts supply chain planning to next level. Nowadays, it is about leaving the stage of creating a forecast and pushing this demand signal upstream. The new paramount is a resilient planning, that uses buffers as decoupling points to separate operational plans from the strategic and tactical plans.[21]

Investing in network visibility inside-out

Immediate focus needs to be on the end-to-end service supply chain visibility. Building a network view to improve visibility of supply chain risks in the own facilities, key tier 1 suppliers and beyond is mandatory. Only if OEMs are capable of tracing potential parts supply chain problems end-to-end, they can respond in a proper manner. Luckily, advanced technologies are emerging that will allow bringing an end-to-end supply chain visibility to a new level at real-time. Technologies such as Blockchain, Big Data analytics, Industry 4.0, track & trace and Additive Manufacturing allow to better tackle the ripple effect and reduce inventory risks more efficiently.[22]

It all starts with the ability to sense and act towards real-time demand and supply constraints. Therefore, enhancing the view on the inbound on-time in-full (OTIF) delivery performance from key suppliers as well as their inventory, goods in transit and shipment status are some of the basic steps. This will allow organizations to project parts stock-outs of components and to optimize customer allocation.

Fig. 6 – Exemplary Control Tower Dashboard for Order Management and Inventory Health



Control Towers are used to provide transparency over order lines at risk or inventory health as an example. This allows organizations to proactively identify and handle exceptions every day's business-as-usual issues by combining insights-driven data analytics and a decision support platform and an organization of supply chain experts. Taking order management as an example, a Control Tower can help to provide insight into delayed orders, quantity discrepancies, and quality variances and thus alert of order lines at risk. Not only does it show the number of impacted suppliers and number of products at risk, but also monitors changes in ETA, quantity shortages, and/or unresolved quality deviations. Furthermore, involved parties can be directly contacted through the system. Additionally, detailed insights about impacted orders and SKUs at risk in case of shortages can be visualized for inventory management. The Control Tower technology provides prioritized insights in products based on days of coverage, combining current inventory levels with planned deliveries and planned consumption.

Overall, the usage of technologies makes it possible to better react to disruptions by improving data quality, decision-making processes and coordination in real-time such as adapting KPIs, inventory policies or changes the parts planning.

Blockchain is one of the technologies here to allow for a real-time trace and tracking to identify disruptions along the supply chain, effectively communicating them along partners and taking actions, such as revising initial schedules or secure more supply stock. Especially regulatory processes, e.g. quality control, customs, can be expedited and have the additional benefit of complying documentation needs.

Taking the BMW Group as an example, they heavily invest into Blockchain technology by their project "PartChain" to achieve multi-stage supply chain transparency. Each and every part has a single ID and can be tracked with its own history using Cloud technologies. This allows BMW not only to monitor procurement origin and track

critical raw materials, but also to detect incidents of counterfeit parts and steer its service lifecycle. For example, mileage is automatically registered and linked to the next maintenance or repair service. No need to manually research and trace customer data, but workshop services can be planned and retrofits neatly managed.[23]

Downstream, the demand side is not to be forgotten. In a world where uncertainty is growing due to economic or political factors, demand sensing is a plus. OEMs work on achieving real-time visibility of customer demand changes, like a decline of projected levels in parts sold or repairs conducted based on the installed base coverage. An understanding of whether it is simply a shift in demand or lost demand will allow to prepare a demand-supply synchronization strategy in order to allocate the right capacities of inventory or service delivery to the right channels and communicate towards transportation providers and field service.

Proactively managing risks and dynamizing the supply chain for resilience

In a world where the installed base is becoming more and more connected, multi-enterprise supply chain business networks are increasing in importance. Those business networks cover all functional domains and connect business partners in- and outside of the organization aiming at better sensing, predicting and responding to supply chain issues across locations, incidents and time horizons. Focus shifts towards using technologies to proactively manage supply chain risks and re-configure for resilience.

Increasingly, digital supply network solutions (DSNs) are being built and designed to anticipate disruptions and re-configure themselves automatically.[24] These solutions are enabled by new technologies, such as 5G, artificial intelligence and machine learning-powered entity resolution platforms, cloud computing and integrating structured and unstructured data, to illuminate extended supply networks. In the background, DNSs use synchronized contingency plans based on a record of activities and data needed for recovery. This will allow for new levels of visibility while simultaneously better understanding demand patterns and shorter response times to service parts requests. Ultimately, delivery risks or reduction of demand can be reduced thanks to higher visibility and information quality that allows to activate contingency plans quickly. Especially Industry 4.0 systems make it possible to leverage flexibility and risks reducing the need for redundant supply chain structures by means of decentralized control principles.[25]

Supreme to build in resilience in supply chains is to use scenario planning in order to predict disruptions and derive configuration options. Create a digital supply chain twin as a baseline to simulate the physical supply chain taking economic, environmental, geopolitical and technology changes into account. Design the network for resilience by simulating broad and pragmatic scenarios based on the biggest risk to the business without making specific projections for an uncertain future in too much detail. Aim here is to run business stress tests for different scenarios and align decision-making along the supply chain while testing contingency plans. With the business model evolving, the scenarios should be updated accordingly, e.g. customized spare parts or a single leading technology might result in a supplier concentration risk.[26] "We are constantly running scenarios per region and product regarding our manufacturing and aftermarket business, we prepare for the worst", says Helmut Ernst, Executive Vice President ZF Aftermarket.[27]

However, most of a company's data today is transactional data not being capitalized on. In today's digital era, getting an extended supply chain view across the network will require a more digital and technology driven approach than in the past. Collecting operative data about servicing activities should be done now. Investing in technologies like IoT to make use of the data, predict and proactively manage incidents instead of merely reacting to chaos is a step that needs consideration, making it possible to emphasize on making more, faster and multiple predictions to get ahead of the demand curve. SKUs, failure rates and order data can be already evaluated today to understand correlations and adjust supply chain strategy.

Humanizing resilience to anchor within the organization

Visibility of the supply chain alone does not provide value and technology alone cannot drive an integrated network. However, it is crucial to cascade objectives and the future supply chain strategy down to the specific projects that support it. What is more, the to-be integrated processes and risk management require a governance model including mandates on risk monitoring, accountability and a scalable risk evaluation approach to be established. It is recommended to establish buy-in within the organization by creating remedial actions with ownership and accountability.

Resilience is not a one-time exercise, but scenarios as well as remedial actions need to be refreshed periodically. Key is to coordinate across the network, while empowering decision-making by individuals instead for quick decisions and mitigation. Only if used with a clear governance model it can lead to more end-to-end robust and intelligent decision making.[28]

In the end, adapting the supply chain also involves adjustments in the daily work routine. In case of a disruption, speeding up decision making is a success factor. In the example of ZF during the German lockdown due to COVID-19, contingency work schedules and multi-level task forces were introduced for all business areas to allow for quick decision-making and empowered teams. "We are running at higher speed than normal and Cash Flow is number two on the daily agenda, following our number one, the health of our people."[29]

Overall, it is about planning for resilience in the end-to-end supply chain and living up towards an integrated risk management policy in network design, rather than primarily paying attention to cost and performance.[30]

Conclusion

Clearly, designing a spare parts supply chain in order to become more robust and resilient is neither a one-day job nor a one-time effort. It takes continous monitoring and adjusting, re-assessing and balancing to find the optimal response to everyday efficiency and cost requirements on the one hand side, and the preparedness for extraordinary threats. Also, the different elements in a supply chain can be changed at the same time – it is important to consider one after the other.

A good point to start with is to conduct a thorough risk analysis to identify the weakest spots in the spare parts supply chain and subsequently define the most urgent and important contingency measures. Fig. 9 provides an overview of those supply chain areas that are primarily impacted by a respective risk.

During conducting the risk analysis, it may quite well turn out that the entire supply chain strategy or fundamental design features of it would need to be revisited. Key considerations, as illustrated in more detail in the sections above, could be:

- Optimized cost position or increased resilience?
- Partnership and collaboration or upstream/downstream?
- Offshore, nearshore or local?
- Single or multi sourcing?
- Digitally automated or manually evaluated?
- Preventative or reactive?

Spare parts are crucial for each and every OEM's customer. Trust once built should not be exposed to risk. There are ways to retain it.

Fig. 7 – Impacted Supply Chain Element Matrix

	Supply Chain Contingency	Supplier Network	Warehouse Footprint	Transporta-tion	Material Categories	Collaboration	Supply Chain Finance	Intelligent Monitoring
Change in dealer network; change in supplier/ distribution selection		✓				✓		
Change in material sourcing		✓			✓			
Change in production/warehousing/distribution footprint		✓	✓					
Delay in production, production downtimes, loss of production		✓						✓
Delay/downtime in service delivery (parts, technicians)								✓
Increase in costs and prices; financial losses							✓	
Long-term loss of business relationships (both suppliers and customers)	✓					✓		✓
Loss of service operations (parts, technicians)	✓							✓
Loss of talent	✓							
Loss of visibility and control over supply chain operations	✓							✓
Mid to long-term changes in international movement of goods			✓	✓				
Slow-down or break-down of material flows; Shortages in supplies			✓	✓	✓			
Temporary breakdown and limitation of communication and business transactions	✓							✓
Temporary breakdown of business activities	✓							✓

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