WORLD ECONOMIC FORUM

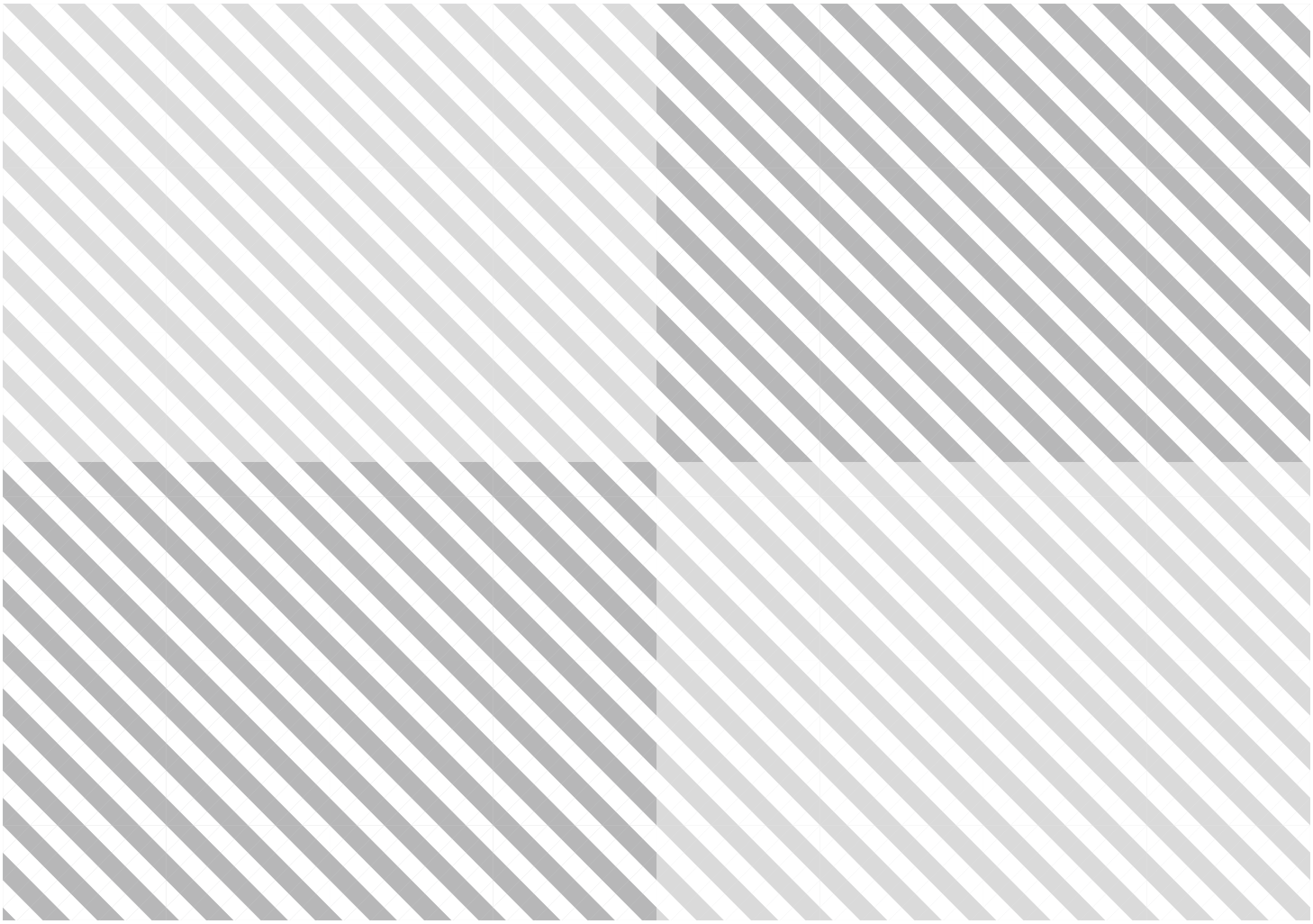
COMMITTED TO IMPROVING THE STATE OF THE WORLD

System Initiative on Shaping the Future of Production

Impact of the Fourth Industrial Revolution on Supply Chains

In collaboration with BVL International

October 2017



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REF 061117 — 00035015

Introduction

At the World Economic Forum Annual Meeting 2017 in Davos-Klosters, Switzerland, the Governors[1] of the Supply Chain and Transport Community, and the Stewardship Board[2] of the System Initiative on Shaping the Future of Production mandated the World Economic Forum (the Forum) to conduct consultations and research to understand the impact of the Fourth Industrial Revolution on the future of production and supply chains.

The Fourth Industrial Revolution is characterized by the convergence of breakthrough technologies – such as advanced robotics, artificial intelligence, the internet of things, virtual and augmented reality, wearables and additive manufacturing – that are transforming productions processes and business models across different industries. Business leaders can no longer focus on developments and trends in their own sectors alone, but need to understand potential transformations and disruptions in the entire world of suppliers, customers and adjacent markets.

In collaboration with the German logistics association BVL International, the Forum has prepared this white paper to outline potential transformations and disruptive developments that technology will bring to the future of production and supply chains across industry sectors. It summarizes the findings gathered by means of consultations and desk research and will be used to inform the discussions that will take place at the 34th International Supply Chain Conference[3], organized by BVL International in October 2017 in Berlin, and at the World Economic Forum Annual Meeting 2018[4] in Davos-Klosters.

Overview and background

Disruptive technologies are transforming all end-to-end steps in production[5] and business models in most sectors of the economy. The products that consumers demand, factory processes and footprints, and the management of global supply chains are being re-shaped to an unprecedented degree and at unprecedented pace. Industry leaders who were consulted believe that new technological solutions heralded by the Fourth Industrial Revolution – such as advanced robotics, autonomous systems and additive manufacturing – will revolutionize traditional ways of creating value. As the costs of deploying technology continue to fall, international differentials in labour costs will no longer be a decisive factor in choosing the location of production.

The resulting greater spatial and temporal flexibility brought about by technology will bring locations of production and sale closer together, and drive major changes in the design of future value and supply chains. These trends will change the shape and form of globalization, and thereby impact the trajectory of goods. Regional and local flows will become more important, to the detriment of intercontinental trade.

Figure 1: The supply chain at the centre of the digital enterprise[6]

Digital workplace	Digital engineering and manufacturing	Digital supply chain	Digital products, services, and business models	Digital customer and channel management
Digital applications				
E-finance Digital HR Internal knowledge sharing	Vertical integration Big data process optimization Predictive maintenance Condition monitoring Augmented reality Integrated digital engineering Digital factory	Integrated planning and execution Logistics visibility Procurement 4.0 Smart warehousing Efficient spare parts management Autonomous and B2C logistics Prescriptive supply chain analytics	Digitally enhanced products Intelligent and connected products and solutions Automated and data-based services Digital business models	B2B2C customer interaction Digital customer experience Omnichannel sales integration Omnichannel marketing Point-of-sale-driven replenishment Microdeliveries Customer lifetime value management
Digital enablers				
Technology, processes, organization				

Source: Strategy&

Through the consultation carried out by the Forum and BVL International, senior executives – including chief operating officers, chief technology officers and chief innovation officers from various industries – provided their perspectives and examples of the main areas across value chains that are subject to transformation and disruption as a consequence of the individual and combined adoption of technologies.

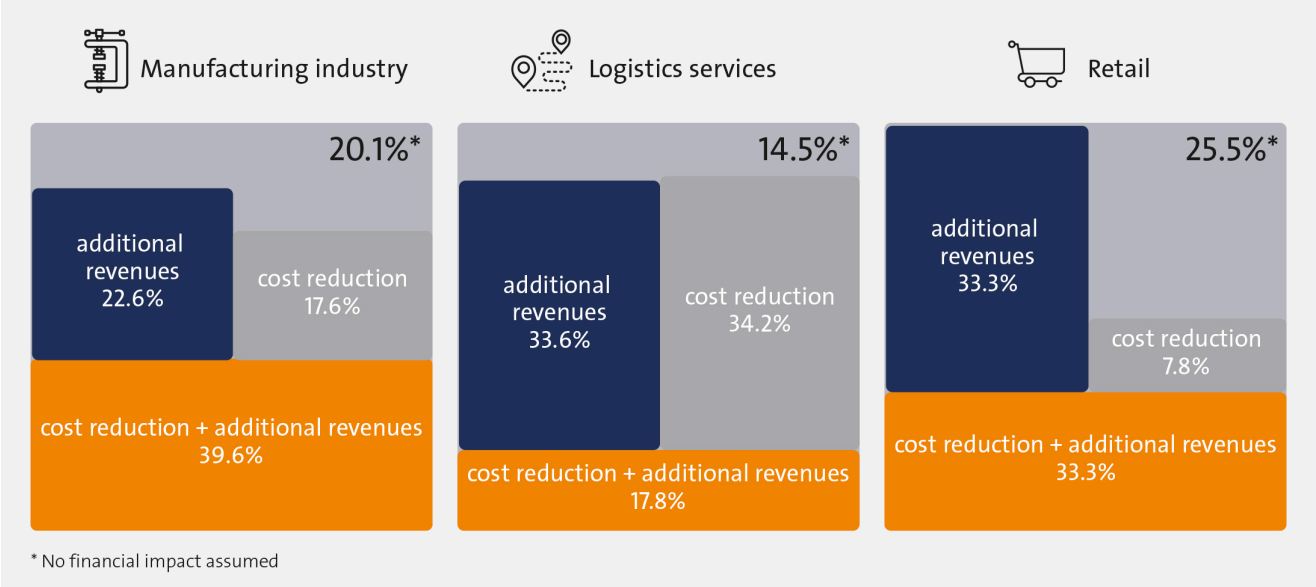
Inputs from business leaders and subject-matter experts informed the identification and definition of the following future developments in production and supply chain.

Key Fourth Industrial Revolution technologies

A vast range of these technologies are already impacting production systems and supply chains. Combined and connected, these technologies will open up new opportunities for creating value across multiple dimensions – for the individual, society, industries, firms and the factory floor.[7]

The ongoing digital transformation of industries also brings new opportunities for innovative business models. The majority of companies in the manufacturing sector (79.9%) and the logistics industry (85.5%) see positive effects resulting from digital transformation (see Figure 2).

Figure 2: Expected impact of digital transformation on the cost situation in companies[8]



Source: BVL International

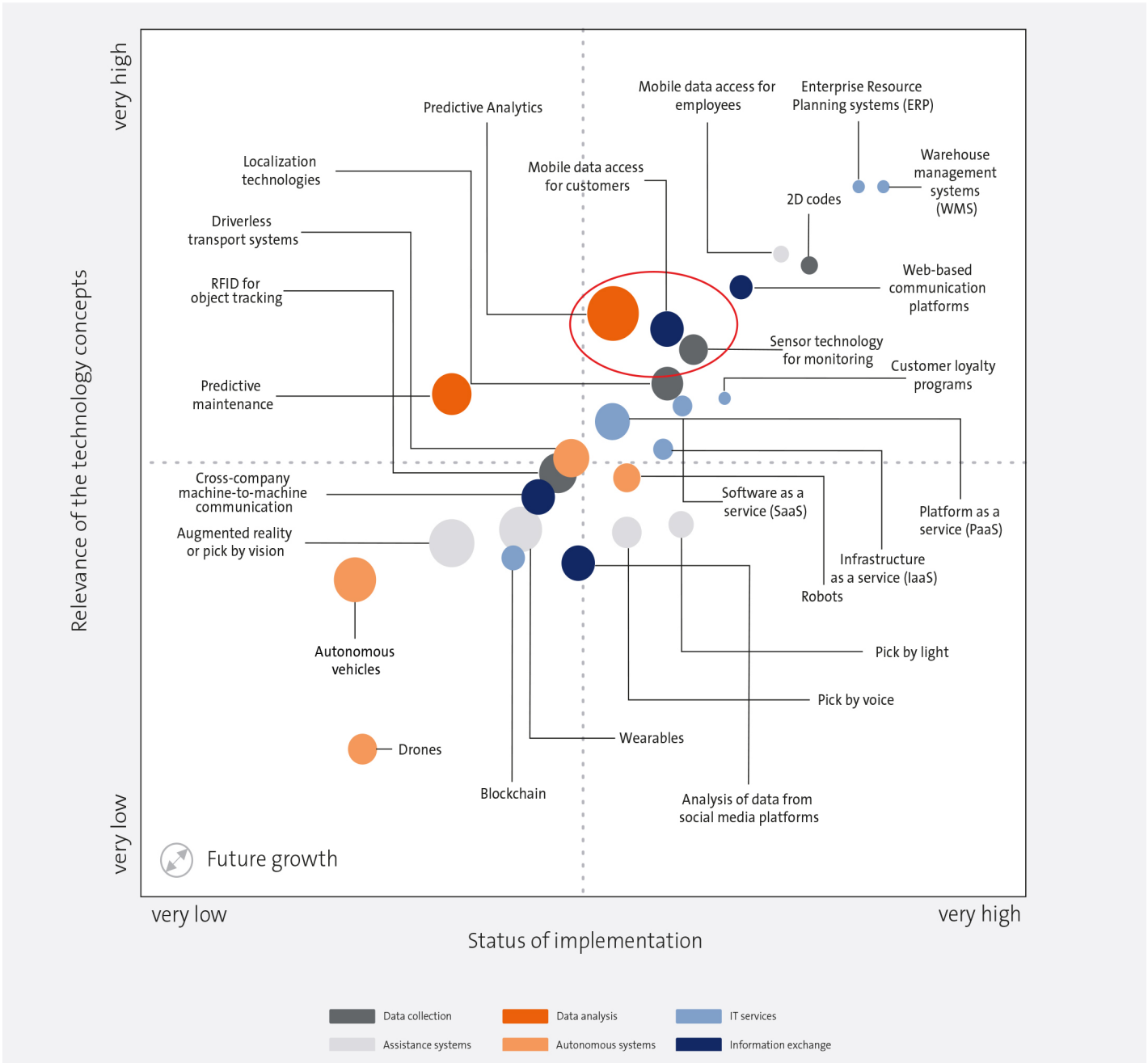
There is a correlation between the relevance of new technologies and the speed of implementation of novel business model solutions. Change in current supply chains is driven by operating and new technologies. Figure 3 landscapes this correlation.

Five key technologies, which are currently at different stages in terms of level of readiness and adoption across industry sectors, are expected to significantly impact supply chains, both individually and in combination: internet of things, artificial intelligence, advanced robotics, enterprise wearables and additive manufacturing.

The internet of things (IoT) is the virtual interconnection of intelligent assets and devices to achieve improved user experience and/or usability. According to Gartner, there will be over 20.4 billion interconnected devices worldwide by 2020.[9] Devices that generate data on a continuous basis are at the core and forefront of the digital transformation of supply chains. Interconnected warehouses that are linked to intelligent transportation systems, and the introduction of IoT platforms which allow for the tracking of all assets and devices in real time, are but some case examples of IoT applications. Smart enterprise control, asset performance management and augmented operators are other areas of application. The opportunities will only grow with the growth of intelligent interconnected assets and devices worldwide.

Connected devices ensure the availability of real-time data, enable the geographic distribution of operations and manufacturing, and result in improvements in operational efficiency, processing time and operating and management costs. They are, however, also prone to cyber risk, which exerts pressure on both government and business leaders to implement appropriate security and privacy policies across organizations, manufacturing networks and supply chains.

Figure 3: The relevance and implementation status of the technological concepts studied [10]



Source: BVL International

While the impact of IoT in the next five years is considered to be high by business leaders[11], experts consider the current degree of implementation of IoT applications across businesses and organizations to be average.[12]

Artificial intelligence (AI) or self-learning systems is the collective term for machines that replicate the cognitive abilities of human beings. Within the broader technological landscape, predictive maintenance in the cognitive era has the potential to transform global production systems. Artificial intelligence, particularly machine learning, is one of the most important general-purpose technologies. AI can significantly help improve performance without human intervention, and allows for constant analysis of performance data, which enables machines to improve over time; whether this is a robot installed in a factory or a distribution warehouse.

Machine-generated insights will pave the way for greater precision and accuracy. While repetitive tasks are performed by machines, people can focus on more complex activities. Physical assets replace low-skilled labour, which requires investment in and upskilling of the existing workforce. This represents a significant change for workers and should be accompanied by the appropriate communication and support of the employer.

The status of current implementation of AI applications across businesses and organizations is assessed as low,[13] whereas the impact of this technology in the next five years is seen as being average.[14]

Advanced robotics is defined as devices that act largely or partially autonomously, interact physically with people or their environment, and are capable of modifying their behaviour based on sensor data. Advanced robotics permeates various industrial sectors, and its reach extends to a wide range of industries. Robotic innovations have been used for recursive manufacturing processes, and have proven useful for workplace safety. The creation of new business models is triggered by the potential of distributed manufacturing as well as the next generation of human-robot collaboration concepts.

Robotics and automation technologies result in shorter cycle times while achieving better floor space utilisation and higher levels of productivity. The introduction of robots near human workers is not without legal and ethical concerns, and also raises regulatory and liability issues. Training requirements are a lesser obstacle to overcome. Concerns about human job security and the question of the appropriate level of automation is a major concern within society. Businesses need to consider the impact on jobs and overall morale across the organization.

Figure 4: Technology use cases, applied holistically across supply chains, have delivered results by improving visibility and data-driven decision making

Value driver	Business problem addressed	Description	Impact	Origin industry	Applicable industry
End-to-end real-time supply chain visibility platform					
Speed to market Agility and responsiveness	Lack of end-to-end (E2E) visibility across supply chain performance, to enable decision making	Installed end-to-end real-time supply chain management software for centralized inventory management & supplier and site performance monitoring	•$80M savings in supply chain costs	Pharma	Consumer Automotive Aerospace Chemicals
Single platform for real-time supply chain decisions					
Resource productivity and efficiency Speed to market Agility and responsiveness	Lack of E2E visibility across supply chain performance to enable decision making	Automated purchasing, sourcing, inventory modeling and tracking onto a single connected platform, enabling simulations and fact based decision making	•20% improvement in productivity •5% reduction in SC coordination costs •5% improvement in on-time delivery	Aerospace	Consumer Automotive Pharma Chemicals
Aggregate demand across end-to-end supplier network					
Resource productivity and efficiency Agility and responsiveness	Delays in supply chain due to poor communication of demand needs across network of sites and suppliers	Deployed a material demand aggregation engine to maps all parts used across all the suppliers that deliver to all sites in the manufacturing network. The engine groups the common parts used at different points in the process, monitors part purchase points and creates visibility to all supplier tiers.	•3-25% reduction in raw materials purchasing costs Trim long tail supplier lists	Aerospace	Automotive Engineering Chemicals

Source: McKinsey

Both the current status of implementation of advanced robotics across businesses and organizations, and the impact of this technology within the next five years, are assessed to be high by subject-matter experts.[15,16]

Enterprise wearables are permanently switched-on, interconnected computing displays that are worn on the human body, for example, for easy, hands-free access to contextually relevant information. These bionic enhancement technologies expand the boundaries of physical barriers. Applications of enterprise wearables are multifarious. Design augmentations and manufacturing processes are key areas of use. Training is another area where enterprise wearables are used – locally and globally. Versatility aspects of this technology, and general privacy and security concerns, have so far limited the introduction of such technologies to the consumer mass market.

The current status of implementation of enterprise wearables across businesses and organizations, and the impact of this technology in the next five years, is assessed as average.[17,18]

Additive manufacturing is the fully automated manufacturing process of building three-dimensional objects from a digital blueprint or model. It paves the way for new designs, manufacturing concepts and logistical services. Additive manufacturing "…could impact goods transportation in much the same way as email impacted letters".[19]

Additive manufacturing is considered a disruptive technology that adds new diversity to products and manufacturing strategies while also creating opportunities for new business models. The most prominent use case example is 3D micro manufacturing.[20] This scaled production and the customization options are becoming even more interesting as manufacturing and inventories can be located closer to consumer markets.

The current status of the implementation of 3D printing across businesses and organizations is considered low, while the impact of this technology in the next five years is assessed as high.[21,22]

Figure 4 shows how technology and digital solutions impact business models and supply chains in three cases.

Technological impact on value chains

With the technologies it brings, the Fourth Industrial revolution changes not only the way in which we produce and manage the supply chain, but also paves the way for the creation of new value chains. Digital connectivity opens up totally new forms of collaboration between companies at various stages of the value chain. The following developments are expected to play a major role in this process going forward:

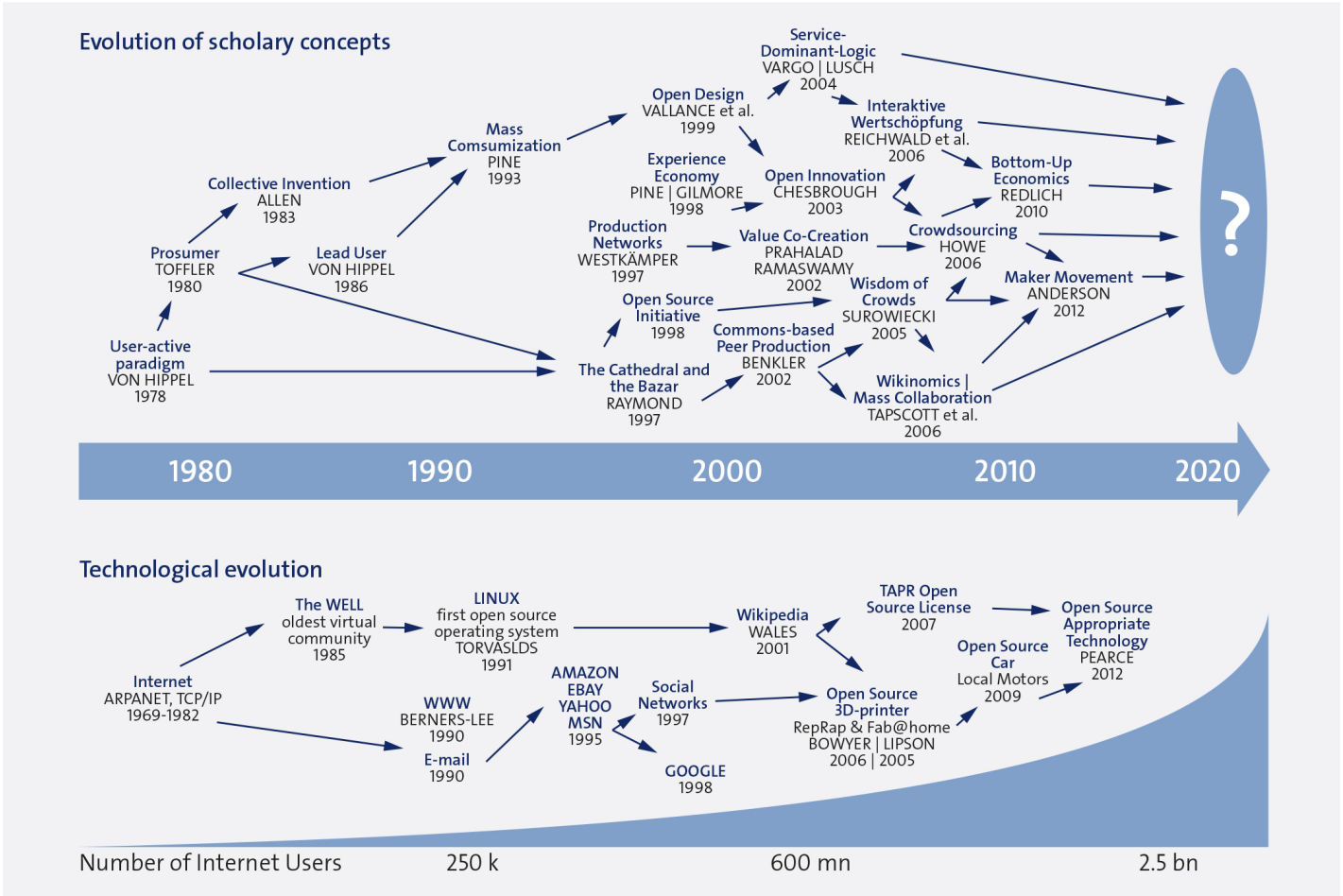
- **Open innovation**, i.e. greater openness of companies towards involving both other companies and their customers in innovation and development processes
- **Distributed manufacturing** as an approach to the comprehensive decentralization of production structures and the elimination of classic manufacturing paradigms
- **New collaboration models** between companies, primarily horizontally, but also vertically

Open innovation

The Internet has largely democratized the way we communicate and innovate. Open innovation platforms can help organizations, regardless of their size or geographical reach, to better innovate by crowdsourcing ideas, designs and other solutions. Oceanographer Edith Widder sums up this practice by stating: "Exploration is the engine that drives innovation. Innovation drives economic growth."[23]

Companies post, for example, R&D-related needs and challenges in virtual spaces, such as open innovation platforms, to crowdsource from an increasingly growing number of contributors. Intermediate platforms, on the other hand, connect companies and experts to solve a specific challenge under intense time pressure. Rewards for participation vary and can be monetary or non-monetary in nature. Open-source ecosystems have emerged as viable tools for value creation in modern times.[24]

Figure 5: Evolution of eclectic concepts and instruments of value co-creation[25]



Source: Redlich and Moritz

The "maker movement" has manifested itself through collective "making,", "sharing", "giving", "learning", "tooling up", "playing", "participating", "supporting" and "changing".[26] Concepts of this kind have significant geographic reach – including developed nations and emerging markets. Today, companies crowdsource product ideas and production designs through global expert networks. The new interconnectedness of people is creating a new balance between consumers and producers. The roles are being redefined and are becoming interchangeable.

Platforms enable the co-creation of value. Figure 5 illustrates the evolution of eclectic concepts and instruments of value co-creation. One rapidly developing area is the field of asset-light, “on-demand” brokerage platforms, which help to match demand and supply of logistics services for on-demand delivery services in cities.[27] The ultimate vision for these platforms is a super-grid that cuts across and helps to coordinate across multiple marketplaces.

Collaborative distributed innovation concepts and platforms bear socio-economic benefits and major potential in both the technological sphere and for more broad-based sustainable development. It is fair to mention that manufacturers are encountering criticism of human alienation associated with industrial change. Companies are called on to rethink their industrial value creation and related activities.[28]

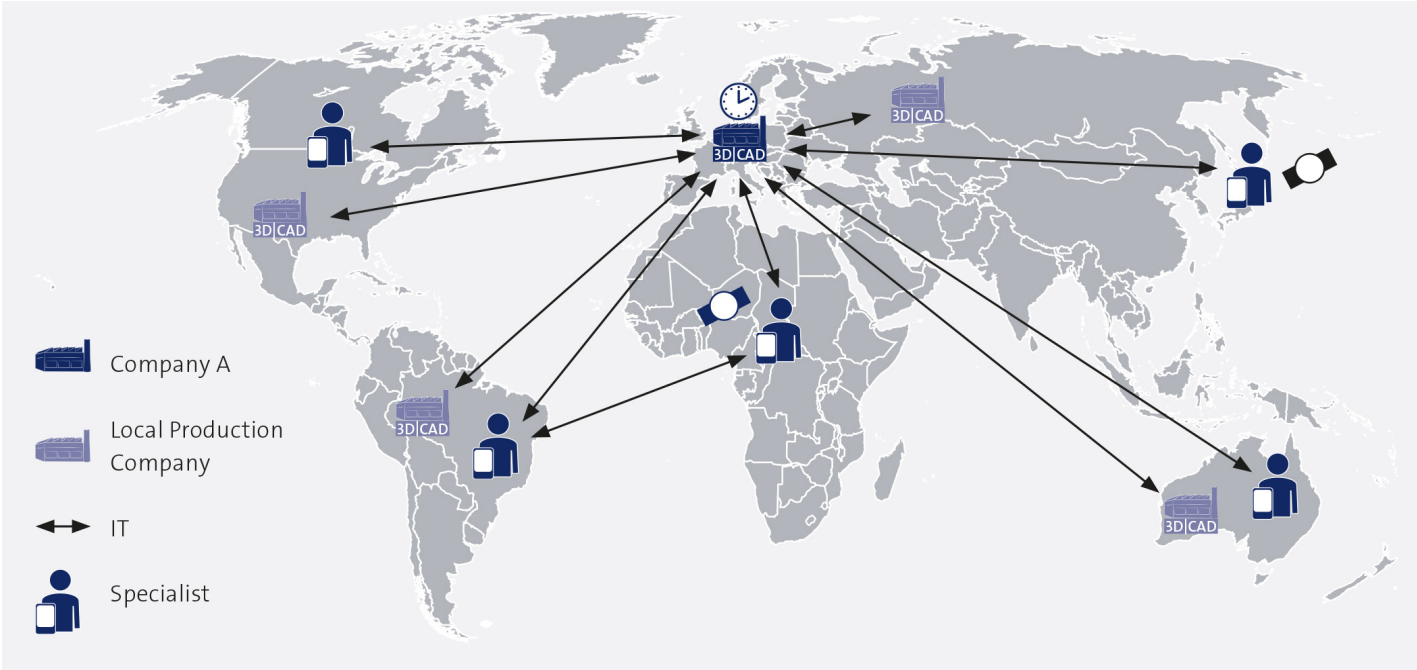
Distributed manufacturing

In all its phases,[29] the process of industrial development over the past 200-plus years has been aimed at achieving economies of scale and consequently unit-cost reduction. This has resulted in specialization and wide-ranging division of labour. This approach was replicated globally with the division of labour between national economies and country specialization, primarily based on resources, capabilities and technologies – with the intent to gradually move up the value chain in selected industry sectors. In the 20th century in particular, this underpinned the emergence of wide-ranging transport and value-added chains which, to a large extent, stand for the term "globalization". The negative consequences of this development, particularly pollution and the effects on the global climate, and social unrest, are largely recognized.

Distributed manufacturing became possible with the emergence of advanced manufacturing technologies. The concept of **distributed manufacturing** was developed in theory and practice on the basis of advanced Fourth Industrial Revolution technologies such as additive manufacturing, the internet of things and cloud computing. The basic idea is to locate production closer to the customer and to integrate the customer more effectively in local production processes. This reduces lead time and costs, and, for example, can be driven by a decentralized network of 3D printers that are interconnected with the producers’ systems via cloud computing.[30]

It is by no means a new approach that companies operate production facilities at various locations to be close to sales markets, such as in the automotive industry. The concept, however, is becoming much more flexible and faster, requiring only 3D printers, with physical supply chains substituted by electronic data connections.[31] Figure 6 shows an example of “distributed production” for wristwatches.

Figure 6: Concept of distributed manufacturing[32]



Source: Brecht and Stelzer

In the distributed manufacturing model, a company can design and produce new series of, e.g. wristwatches, involving the customer in the design throughout the various steps of customization and adaptation. This means customers get actively involved in value creation. Moreover, in distributed manufacturing, the goods are produced at local level, closer to consumers. The company can commission different factories with adequate tools and sufficient capacity to produce watches. The largely personalized designs are sent to 3D printers and computer numerical control (CNC) machines for production. The co-creation process not only yields a product that is highly customized to the needs and desires of customers involved, but that is also of high quality. Furthermore, the process unlocks significant future potential for the company.[33] The example shown clearly illustrates the **characteristics** of distributed manufacturing:[34]

- **Digitalization** of product design, manufacturing control and involvement of the customer enable new designs and central (location-independent) quality control
- **Localization** of manufacturing sites and material stocks close to markets allow for high flexibility and speedy response
- **Personalization** of products (lot size 1) in high quantities and therefore the possibility of mass customization
- **Advanced production technologies** suitable for a broad-range of applications are paving the way for improved efficiency
- **Involvement** of many partners in the value chain, including designers, manufacturers and consumers

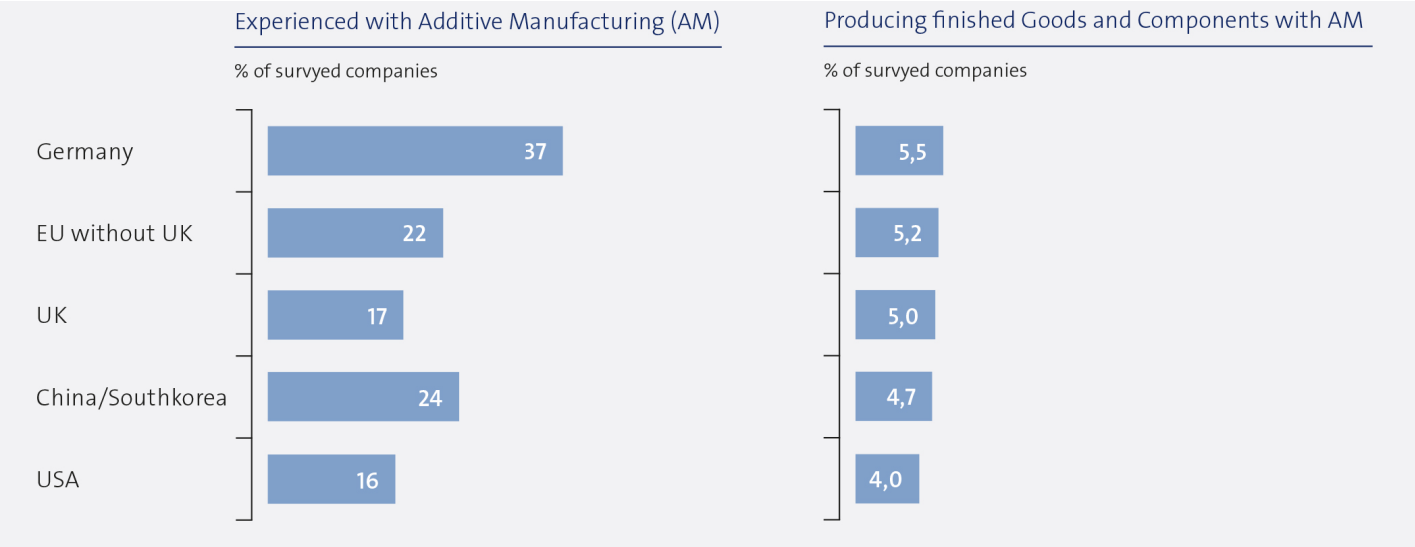
Distributed manufacturing could lead to a paradigm shift in manufacturing. Centralized mass production will be gradually replaced by decentralized, i.e. local manufacturing of customized products. Rigid linear value chains will be replaced by agile networks of a broad range of parties interacting in real time. Planning cycles can be significantly shortened, and customers get involved in the production process.

The shortening of supply chains leads to reduced transport costs and CO_2 emissions. The flip side is the still significant investment in establishing decentralized production capacity and the higher unit costs compared to centralized mass production.[35]

The central manufacturing technology in distributed manufacturing is additive manufacturing. For this reason, the development progress, market penetration and production quality of additive manufacturing are critical success factors. The global market for additive manufacturing was estimated at $4.1 billion in 2014. Revenues generated from the sale of products made by 3D printing technology reached $1.3 billion. Subtracting the material costs, the value added totalled $660 million, which represents a mere 0.01% of global industrial value added.[36]

Figure 7 summarizes the findings of a study by EY, in which manufacturers were asked about their experience with 3D printing.

Figure 7: Survey on experience with 3D-printing[37]



Source: EY

According to the study, German companies possess the highest level of experience with 3D printing. They are also leaders in applying the technology for manufacturing finished goods and components, albeit still at a very low level: only around one in every twenty companies uses 3D printing manufacturing technology – annual growth is estimated to be around 30% up to the year 2020.[38]

Distributed manufacturing will continue to benefit from many trends and developments:[39,40]

- **Environmental pressures:** CO_2 emissions rose by over 50% in the period from 1990 to 2011. Freight transport accounts for roughly 13% of all energy consumption. CO_2 footprint will play an increasingly important role for companies – as, therefore, will strategies to reduce or avoid CO_2 emissions.

- **Cost pressure:** There is a need for companies to constantly reduce logistical costs, mainly transport and storage.
- **Mass customization:** Customers require personalized goods at low costs. Distributed manufacturing with the use of 3D printing offers a solution.
- **"Glocalization" and near-shoring:** Lead times become increasingly important for consumers. Distributed manufacturing implies proximity of manufacturing to markets and short response times.

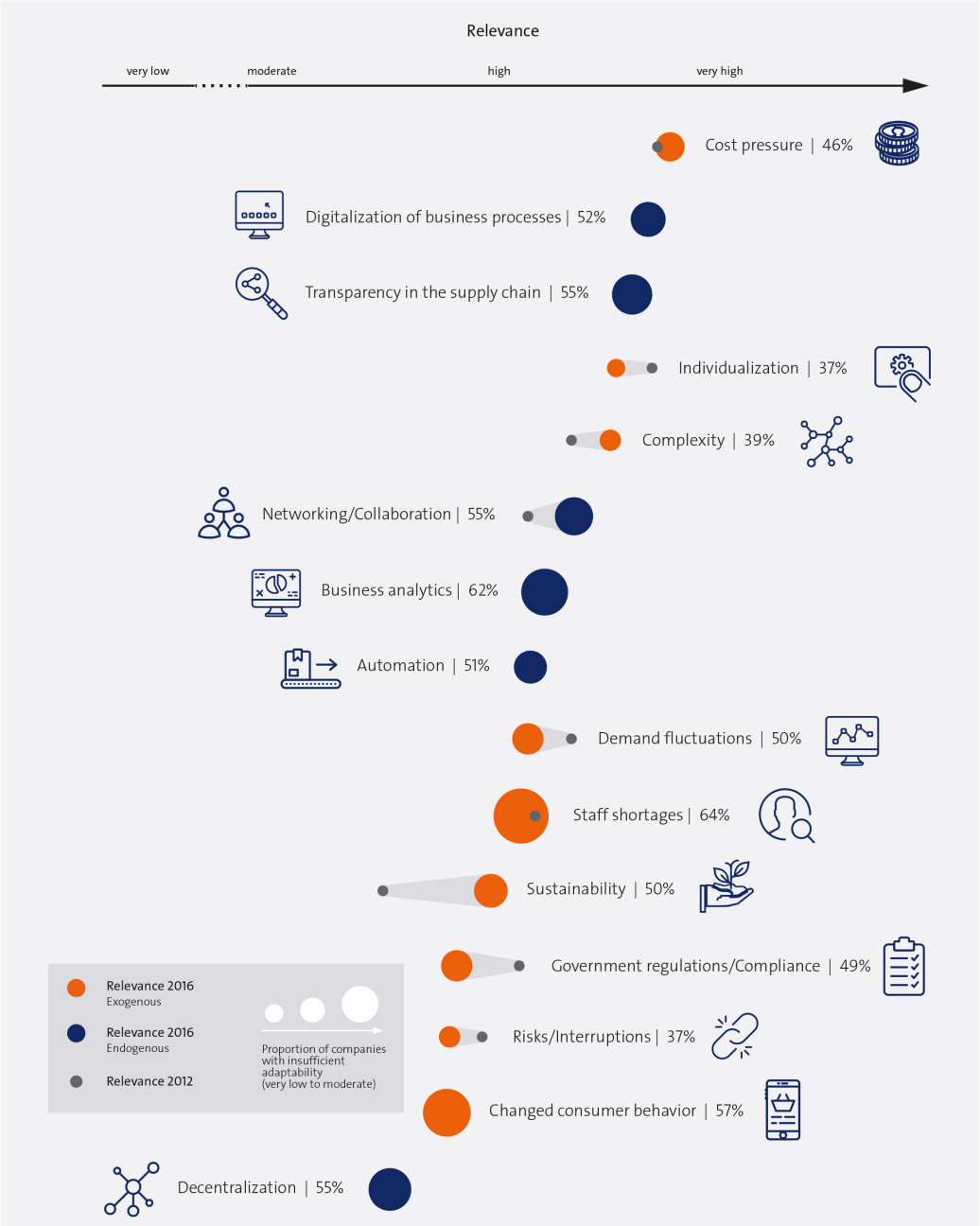
Nevertheless, widespread use of the technology is not a given. Successful application of distributed manufacturing requires overcoming the following **challenges**.[41]

- **Lack of proven technology and infrastructure:** Availability of functioning and resource-efficient production technology is a pre-requisite for the success of distributed manufacturing. At the same time, digital infrastructures need to be widely available to comprehensively interconnect manufacturers and consumers – and also to incorporate other third parties in an open co-creative and innovative approach via respective platforms.
- **Governance and regulatory issues:** There are unanswered questions and pending items from a legal point of view, in particular about liability and intellectual property (IP) protection. Additional concerns result from potential micro-factories established in mixed-use or residential areas.

New collaboration models

The supply chain is a collaborative ecosystem. Over time, many forms of collaboration between partners along the supply chain have emerged. Digitalization pushes this reality to a new level of complexity. Consequently, company

Figure 8: Relevance of current trends in logistics and supply chain management[42]



Source: BVL International

boundaries are becoming less and less important in the endeavour to improve the efficiency and resilience of supply chains. There are several reasons for this:

- **Technological foundations** are in place in the form of cloud computing and user-friendly platforms
- **Collaboration** is recognized as the way to master the complexity of the supply chain, including environmental and cost pressures, and the increasing demand for personalization
- **Companies are ready** to collaborate not only vertically with their suppliers and customers but also horizontally across industry sectors to capture more opportunities.

Figure 8 shows that, according to a survey conducted in 2016 among logistics and supply chain management executives and experts, networking and collaboration ranks sixth in terms of key trends driving the transformation of value chains, moving up in importance compared to the same survey in 2012.[43]

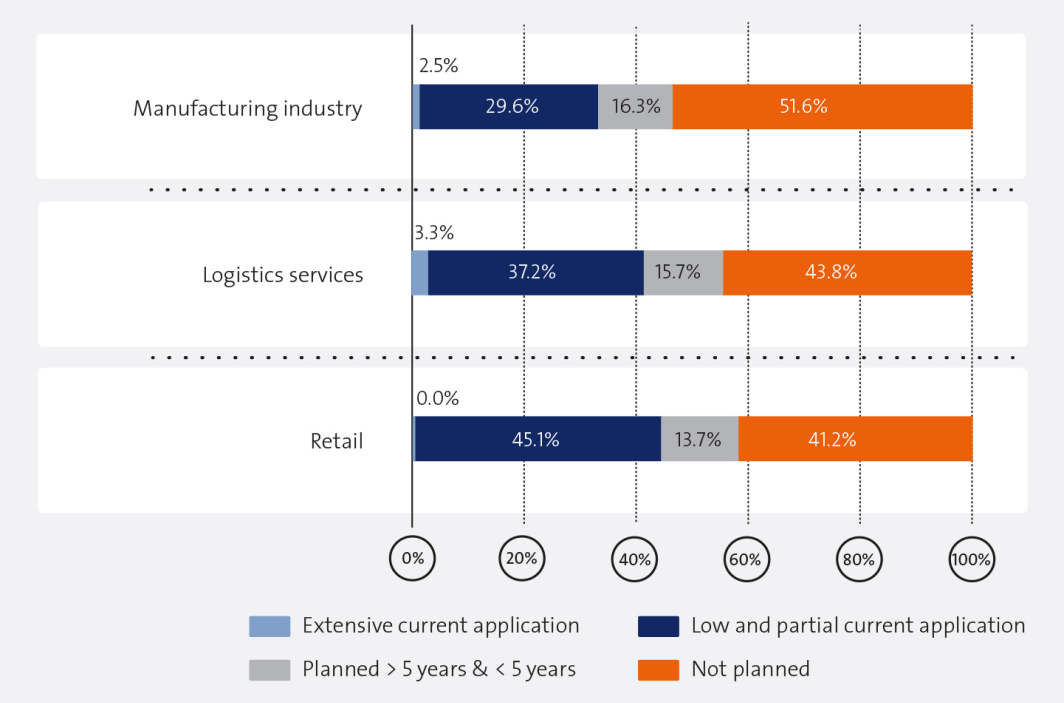
While vertical collaboration models are common across industries, and generally in the interests of all stakeholders along the different steps in the value chain, horizontal collaboration is often seen as a risk from a competitive standpoint. The competitive situation between companies is regularly seen as an impediment to capture optimization potential. Horizontal collaboration, however, is motivated by the high potential for cost savings through joint procurement services and shared use of transport and storage capacities. Also, the sharing of information to mitigate risks along the chain is seen as a driver of horizontal collaboration.

Technological impact on logistics

The Fourth Industrial Revolution also impacts the logistics sector. Innovative business models in the field of supply chain management can result from the evolution of existing products and services but can also represent a fundamental change in the way logistics services are produced and delivered. The four dimensions "customer", "performance", "value creation" and "profit model" are key elements of business models and underpin the fact that an innovative or new business model must not be limited to product innovation and novel services. The new business models, currently under discussion and development, would have been unthinkable without digitalization. Two features that are characteristic of new business models in logistics are the intensive use of data and the digital interconnection of all partners along the value chain.[44]

Logistics service providers (LSP) will need to reinvent themselves as technology companies to adapt to the paradigm shifts that the Fourth Industrial Revolution already initiated or will trigger in the future. Third- and fourth-party logistics service providers (3PL and 4PL) need to develop and launch new business models that can serve their changing customer base, current and new. The resulting transformation of the logistics industry is likely to further blur the borders between manufacturing, retail and logistics. Figure 9 suggests that today, some 44% of logistics companies still focus on traditional business models, whereas 37% of logistics providers have already digitized smaller or larger parts of their business models.[45]

Figure 9: Digitalizing business models by sector[46]

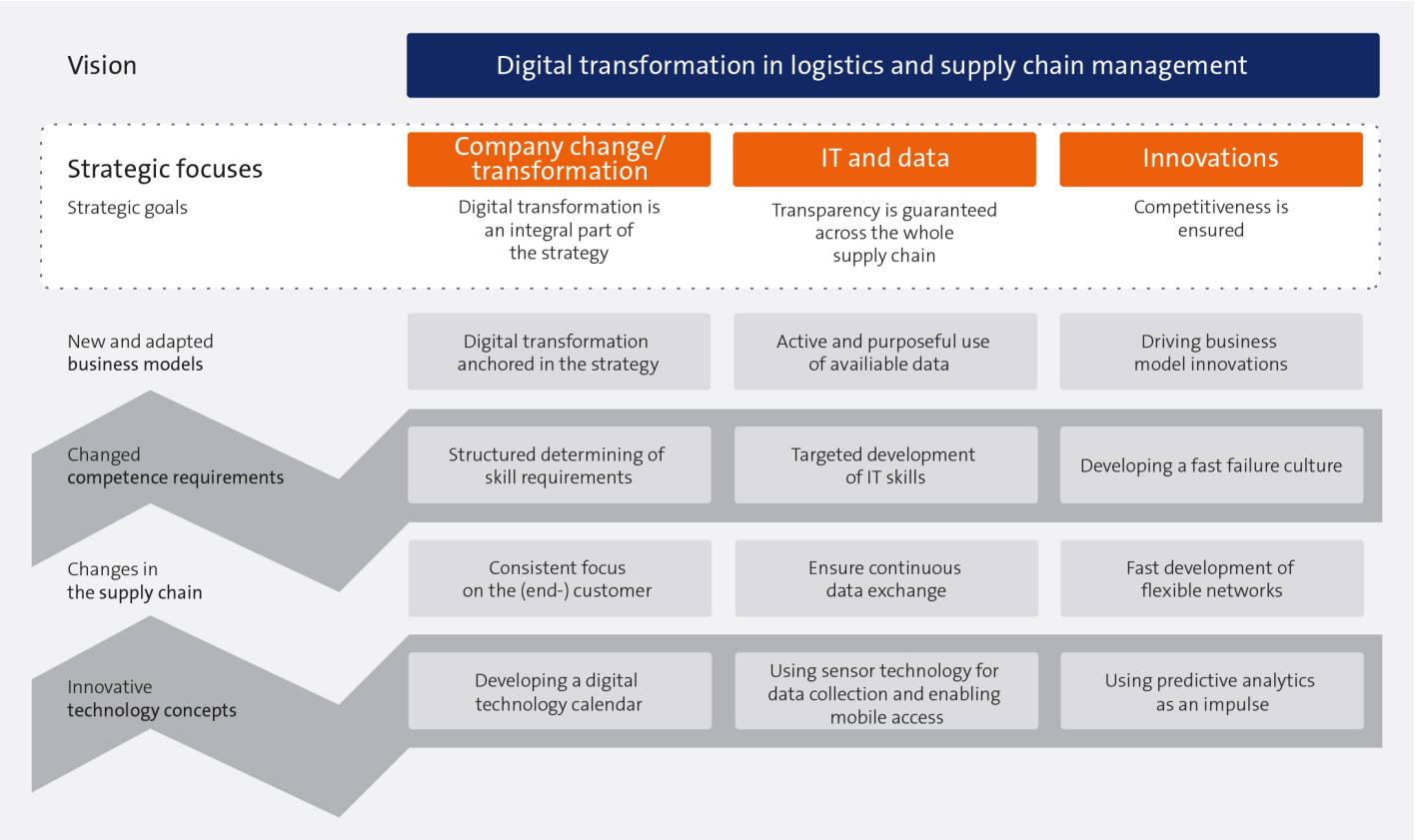


Source: BVL International

Logistics service providers need to define their strategic road map on how to respond to the digital transformation of logistics and supply chain management, internally and externally. Decisions need to be made on whether to expand existing business models or to shape new business models. Figure 10 highlights the prospective areas of strategic focus on the path towards defining a vision of digital transformation of organizations. The figure highlights new and adopted business model opportunities, and the resulting and required changes both in the supply chain and competencies required.[47]

A huge opportunity for LSPs that emerges in the wider context of digital transformation accrues from their expertise in orchestrating complex supply and manufacturing networks. Orchestrating is a key competency in the interconnected world. Taking on activities such as final assembly of products and product customization has been the starting point for the reinvention of the traditional logistics sector.

Figure 10: Strategy map for digital transformation [48]



Source: BVL International

Challenges to technological advancement

In embracing technologies that enhance connectivity along the value chain, companies will also need to prepare for the cyber risks to which they will be exposed. Fourth Industrial Revolution technologies enlarge the enterprise risk landscape (see Figure 11). Cyber dependency comes with high exposures and risks, and requires new and effective risk management strategies and tools.[50] Cyber-attacks can be targeted and untargeted, systemic and non-systemic. The supply chain is a potential target of cyber-attacks. A non-systemic cyber risk impacts individual parts and components of a critical infrastructure ecosystem, whereas a systemic cyber risk impacts entire ecosystems.

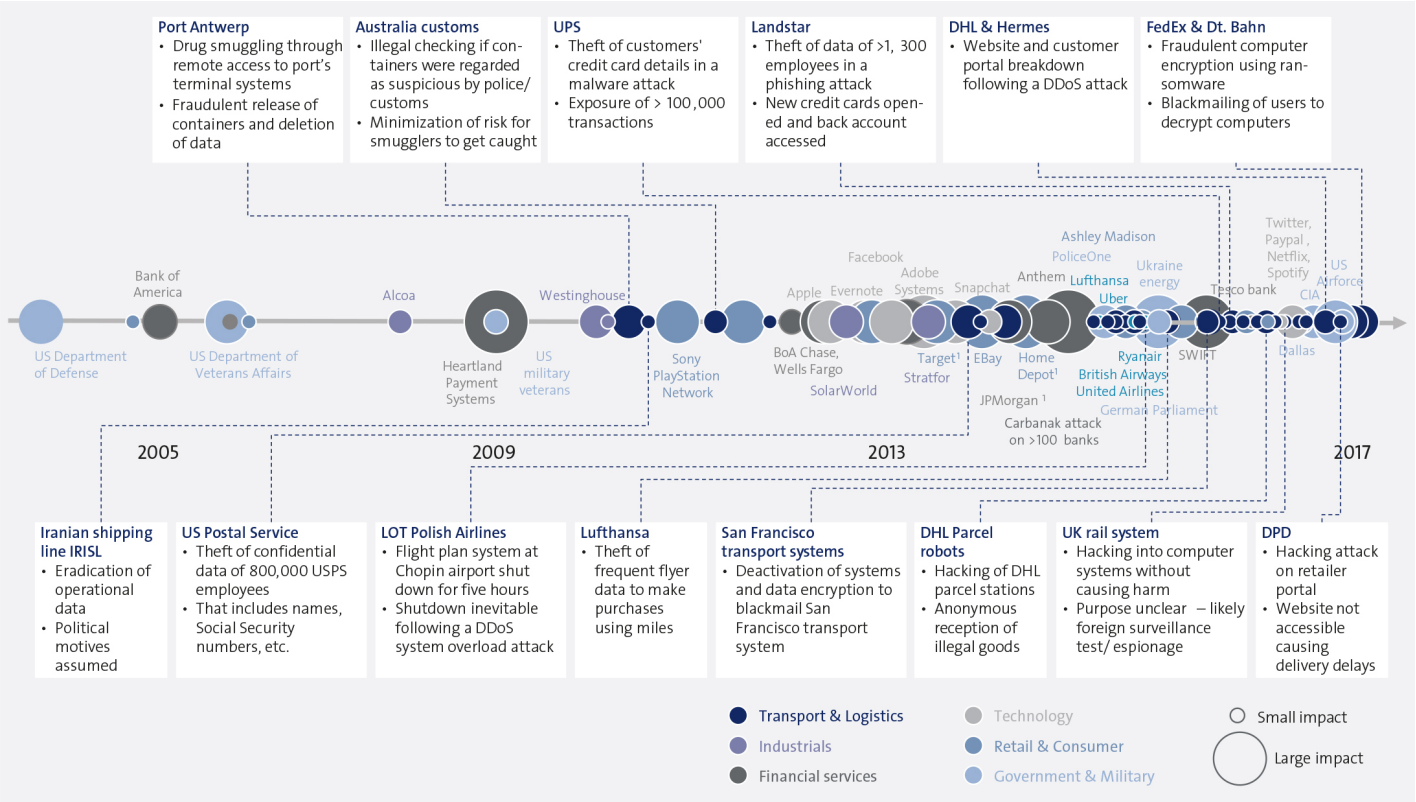
Figure 11: Enterprise risk landscape[49]

Source: EY

Figure 12 shows an overview of the frequency and magnitude of cyber-attacks from 2005 to 2017. One ransomware attack called "wannacry" in 2017 is a recent example of global reach and impact. Approximately 300,000 computers in over 150 countries were infected. The cyber-attack was not of a sophisticated nature, as the data of the infected computers was simply encrypted and a payment was demanded for the release of the data.[51]

These kinds ofincidents underline the vulnerability of businesses and organizations. If systemic cyber-attacks were to be carried out industry-wide, the impact would probably be severe. The changing technological landscape means that stakeholders should not only protect current operations; future business models also need to be designed by taking into account potential cyber risks. Risk management strategies need to be customized and updated frequently to respond to new and novel trends and threats. The main challenge is the uncertainty regarding the characteristics and scope of future risk incidents.

Figure 12: Past cyber-attacks[52]



Source: Oliver Wyman

Implications for the environment

The quantity of CO_2 emissions depends on the mode of transport (see Figure 13). The technologies associated with the Fourth Industrial Revolution can bring significant ecological benefits. Quantifying these effects, however, is challenging; not least due to the broad range of technologies at play and the broad range of areas of application.

Company-specific studies indicate emission reductions of up to 25% due to, among other things, the following practices (cf.)

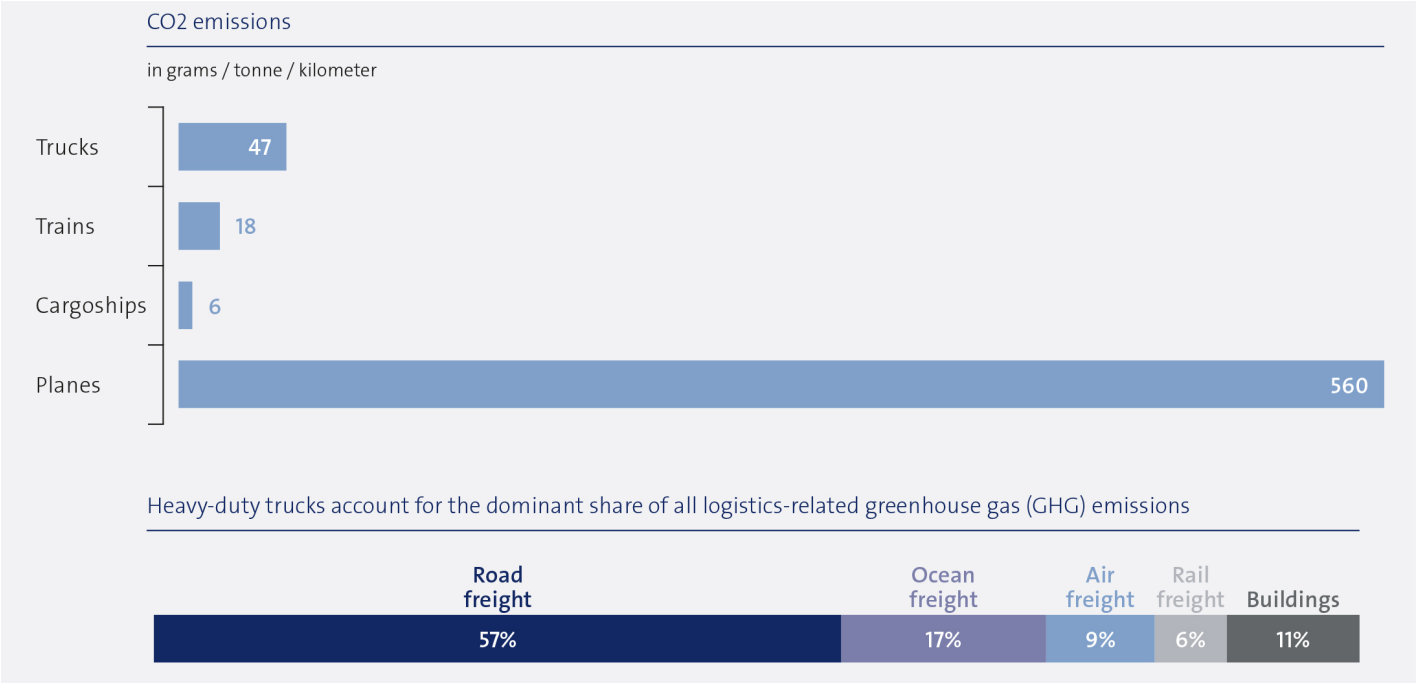
- Digitalization of business processes
- Sensor-based monitoring of technical systems in real time
- Data analytics and predictive maintenance of machines[54]

The concept of distributed manufacturing implies significant changes in supply chains. Less global and more regional and local logistics services are required. Distributed manufacturing, and in particular 3D printing, are associated with the following positive impacts on the environment:

- **Efficient use of materials:** There is hardly any unused material in 3D printing, as only the raw material that is actually needed is processed.
- **Reduced material load:** Three-dimensional production processes can realize highly complex lightweight structures. This can have positive effects on energy needs and the lifecycle of the corresponding components.
- **Efficient production:** Energy for producing machine tools and their transport along the value chain can be avoided by applying 3D printing technology.
- **Reduced transport:** Proximity to the markets of manufacturing sites reduces long distance transport requirements and associated CO_2 emissions. Instead of semi-finished and finished products, it is mainly raw materials – which are more suitable for cost- and energy- efficient mass-transport modes such as railways and ships – that need to be transported. Moreover, demand-induced production is expected to reduce returns, as supply should fit demand.[55]

However, 3D printing can be more energy-intensive than conventional mass-production methods.
Both the mode of transport and the weight of goods impact the level of emissions. 3D printing affects both levers. A case study in the area of spare parts logistics in the aviation sector indicates the potential to reduce emissions by up to 40% through changing the mode of transport. In addition, when the reduced weight of 3D-printed components is factored into the equation, the saving is 100 times higher.[56]

Figure 13: Comparison of transport modes[53]



Source: Freightera

Implications for jobs

Fourth Industrial Revolution technologies are not only changing the supply chain ecosystem but also transforming the world of work. They are re-shaping the profiles and skills needed. Enhancing capabilities is no longer sufficient, as new skills need to be acquired to monitor the technologies and master new production processes. Human resources policies and programmes need to facilitate the change and support the transition process if disruptions are to be avoided.
Companies need to assess, develop and enhance their workforce in line with future requirements. The following factors describe as well as impact the situation, and also raise questions:

- Skills shortage – how will talent be secured in the future?
- Migration - what role do immigration and foreign workers play in securing the future of manufacturing and supply chains?
- Automation of (operational and administrative) processes – what role will traditional job profiles play?
- Personnel development – how to design future career plans?
- Changes in regulations and legal framework conditions – how will co-working be organized between human workers and robots?

Several industries, including logistics and supply chain management, are facing significant talent shortages that might threaten their global market position.[57] The importance of human capital is rising and talent is seen as a competitive factor. The adjustment of human resource policies and practices to support the digital transformation requires in-depth understanding of the impact of Fourth Industrial Revolution technologies on the labour force.

The replies of over 350 supply chain and operations professionals in five major regions of the world indicate a gap between today's highly valued competencies and future skill requirements. The survey conducted by DHL Supply Chain suggests that the following top skills will be required in future:

1. Leadership
2. Strategic and critical thinking
3. Problem-solving skills, creativity and imagination

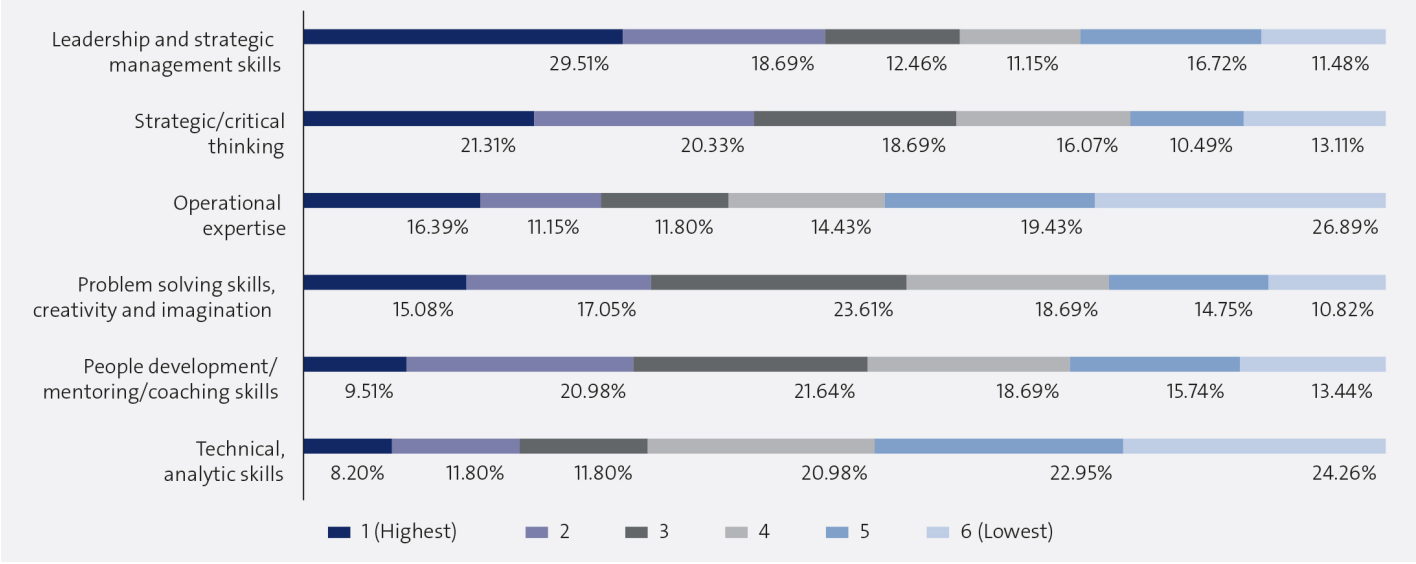
The surveyed companies do not place technical and analytical skills above strategic abilities (see Figure 14).

Companies need to build robust talent pipelines to stay competitive in their industry. An action framework could help to establish an ecosystem for reskilling and right skilling: defining the required actions for the public and private sectors and possibly other stakeholders, recognizing current and future skill requirements, and identifying the appropriate learning techniques and methodologies.[59]

Technological developments combined with social change have implications for current job profiles and the low-skilled labour workforce. An Oxford University study suggests that low-skilled workforces will shift to tasks that require creative and social skills, and which are not susceptible to digitalization.[60]

The discussion about jobs at risk has turned into a discussion about shifts in required jobs. A new form of flexibility will be required for humans to work alongside Fourth Industrial Revolution technologies such as robots. New job profiles will emerge. Significant demand has already emerged in the space of cyber risk, cybersecurity and resilience.

Figure 14: Skills for supply chain managers of the future[58]



Source: DHL Supply Chain

Preliminary considerations for Fourth Industrial Revolution-driven supply chains

- **New roles and capabilities:** In the context of current and future dynamics, the enhancement and change of roles and capabilities – such as the implementation of open innovation as well as horizontal collaboration concepts – will define competitiveness and "compatibility" advantage in the Fourth Industrial Revolution Along the supply chain, the roles of stakeholders are likely to change. Companies need to prepare for this development.
- **Supply chain performance:** "Through 2018, 75% of companies will struggle to realize their end-to-end supply chain visibility" (Gartner). The lack of end-to-end supply chain knowledge slows innovation. Fourth Industrial Revolution technologies and data collection are not being leveraged to the fullest extent possible. More than 75% of supply chain executives claim they have limited, selective or even no information on their supply chains. To transform supply chains, a new level of supply chain visibility needs to be achieved.[61] Fourth Industrial Revolution technologies, such as the internet of things and artificial intelligence, will prepare the ground for the necessary transformation.
- **Organizational agility:** Traditional supply chains have been optimized and stretched to a high degree. The number and amount of products, suppliers and customers added has increased significantly. The integration of supply chains is reaching its limits. The additional layers have added complexity and are constraining the originally laid-out infrastructure.[62] In addition, new customers with new expectations emerge. New forms of structural and organizational agility need to be achieved. Fourth Industrial Revolution technologies will enable the shift.
- **Ecosystem for skilling:** Shortage of talent and the right-skilling challenge will remain. These technologies but also new innovation and partnering models already require new competencies and skills – at all levels. A multi-stakeholder ecosystem for skilling is needed.
- **Support for SMEs:** Large corporations are able to make major investment in research and development, but small and medium-sized enterprises (SME) are major contributors to growth and job creation. Governments need to ensure that SMEs can also capture the benefits of Fourth Industrial Revolution technologies. Investment in these technologies, such as distributed manufacturing, will also help emerging nations realize and accelerate their industrialization process.[63]
- **Leadership:** A pre-requisite for successful navigation through the Fourth Industrial Revolution is leadership. This age requires that we overcome company and industry boundaries – networks imply collaboration. Today, most companies and even competitors can only succeed if they collaborate. Collaboration requires an open mind, skills and willingness and support from the top.
- **Neutral platforms:** The shaping of the Fourth Industrial Revolution is a co-creation effort that requires spaces for the exchange of ideas, information and experience to support the implementation of new roadmaps. These co-creation platforms have to be neutral and as much digital as traditional in nature.

While a serious attempt has been made by the authors to take the perspectives of all contributors and workshop participants into account, it has not been possible to do justice to the broad variety of views and inputs. This white paper should therefore not be considered as representative of a consensus. Instead, it remains the responsibility of the authors. The purpose of this paper is to provide an overview of anticipated developments; their impact on supply chains is to be further explored and refined.

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Endnotes

[1] The Governors community in each industry sector is composed of the global chair/chief executive from the leading companies shaping the global future of the industry.

[2] Stewardship Board: A group of 40-50 Ministers and Chief Executive Officers, who provide strategic guidance, champion the initiative and mobilize their organizations to shape the future of production.

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