Unveiling the Challenges of Future Supply Chains: An Explorative Analysis

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Abstract This chapter focuses on the identification of challenges that supply chains of the future will most likely face. The primary input in this process are the potential optimistic/pessimistic/intermediate future scenarios based on trends within political, economic, social, technological, legal, and environmental dimensions. Based on such input, we present a list of major challenges/opportunities in relation to the design and operations of Supply Chains (SCs) in the near future. The preliminary list is calibrated and validated based on the input from industry stakeholders (to account for the perspectives of different supply chain actors such as buyers, suppliers, policy makers, and supply chain facilitators) in order to make sure that these challenges are indeed of practical relevance and grounded in reality. The aforementioned challenges are aggregated into several clusters aiming at providing decision makers with a tool that would enable them to quickly and easily spot the relevant challenges and take proper actions to mitigate any potential risk.

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1 Introduction

Based on the recent political, economic, social, technological, legal, and environmental trends, Sardesai et al. (2020) present six macro scenarios: two optimistic (PrOCEEDINg, aSPIRANT), two pessimistic (UNEasE, ENDANGEr), and two intermediates (oFFsET, DiThER) while the implications of such future projections in terms of how supply chains will be designed and operate are discussed in more detail in Barros et al. 2020.

In this chapter, we take into consideration the supply chain dimensions as defined in the consequence matrix presented in earlier chapters (i.e. sourcing strategy, distribution, supply chain integration and finance) for the identification of challenges.

In Sect. 5.2, we present a short literature review on the identification of the challenges for the supply chains and the most important topics to be addressed; Sect. 5.3 discusses the methodology employed for the identification and validation of the challenges which are described in more detail in Sect. 5.4, proposing an easily navigable presentation of such challenges under a few clusters and categories. We conclude the chapter with a brief discussion of the main findings in Sect. 5.5.

2 Literature Review

Most of the existing studies analysing specific challenges in supply chains focus on some specific application or domain. Recently, significant emphasis has been placed on the field of "sustainable logistics and supply chains", which are believed to be the engine for a more competitive and unified European market. In order to design consumer driven supply chains meeting the needs of more sophisticated and demanding customers without losing the competitive edge in global markets, logistics must be highly efficient, reliable, agile/responsive, safe, secure, environmentally friendly, and cost-effective. In this section, we present findings from the related literature on such supply chain challenges, and present the ones that are particularly related to the manufacturing, process industry, and logistics.

While building agile and responsive supply chains is a challenge by itself, the pressure to transform supply chain processes and activities into sustainable operations brings new challenges to the table. Abbasi and Nilsson (2012) based on a literature review, identified five major areas of challenges for supply chain management in this regard: costs, complexity, operationalisation, mindset and cultural changes, and uncertainties.

Boström et al. 2015 identified six gaps to achieve sustainable and responsible supply chains and networks: (1) geographical gaps, linked to the distance between the production of commodities and their consumption, impacting production from an environmental and social standpoint; (2) information and knowledge gaps which create needs, e.g. reliable, comprehensive, verified and credible information about sustainability impacts of products and production processes; (3) communication gaps

along the chain to ensure a responsible conduct; (4) compliance or implementation gaps, e.g. the norms in codes of conduct, eco-labelling scheme, and so forth; (5) power gaps, related to achieve power symmetry or more equal distribution of power among chain and network actors. This is also linked to energy and resource supply uncertainty (Beamon 2008). It is still necessary to improve efficiency in resource use, material storage, material movement, and product design; (6) credibility or legitimacy gap, where Governance arrangements are developed. Furthermore, some challenges are related to the inadequacy of measures to minimise advance logistics negative effects and include (Clausen et al. 2016): (1) reduction of the environmental impacts (e.g. carbon footprint, noise, un-safety and inadequate land use) to "become environmentally sustainable, imposed by the increasing global awareness and commitment to preserve resources and reduce emissions" (Mason et al. 2007); (2) reduction of the demand for non-renewable resources; (3) improvement of external safety and labour conditions.

This transformation into sustainable operations is fostered by the development and adoption of technology, especially given the problems associated with communication, information, and knowledge gaps. However, adoption of such technology is easier said than done. Digitalization and the use and evolution of Information and Communication Technologies require (Barreto et al. 2017) transparency and integrity control (right products at the right time, place, quantity, and cost). According to Butner (2010) a more complex, costly and vulnerable supply chain is due to a higher number of suppliers and information flows to manage which implies a need for a smarter supply chain. Digitalisation through blockchain technology requires collaboration and system integration to operate smoothly. Parties involved need to agree on a given type of blockchain to use (Galvez et al. 2018). However, although the blockchain is perceived as a highly secure decentralised data infrastructure, hacking is still possible (Wang et al. 2019). Data is used for forecasting in supply chains. Nevertheless, the existing trend towards high granular data raises the question of what aggregation level to forecast on, and usually lead to the problem of forecasting intermittent time series (Syntetos et al. 2016).

In addition, the creation of megacities and demographic changes (e.g., people getting older) bring new challenges for the corporate world and the society, some of which might also be addressed through the adoption of new technology. Most of these challenges are linked to risk attitude, mobility and certainly changing consumer behaviour. Specific implications on logistics in this regard would be linked to the need to build a network of distributed warehouses, long-haul and complicated urban last-mile delivery operations and other workplace environments (Clausen et al. 2016).

Van Breedam (2016) provides a nice framework under which challenges can be structured along three elements: (1) changing environment, (2) changing customer behaviour, and (3) changing logistics. According to the author, changing environment is related to the challenges in the following domains: demography, urbanization, globalisation-glocalisation, the sharing economy, the servitisation economy, the circular economy, corporate social value creation, and supply chain risks. Five common risks arising across various types of supply chains include macro risk, demand risk, manufacturing risk, supply risk and infrastructural risk (information,

transportation and financial risks) (Ho et al. 2015). Meanwhile, changing customer behaviour is linked to areas such as: on demand, omni-channel, product innovation, and speed of change in ICT technology. In this book, these challenges have been identified as trends (see Kalaitzi et al. 2021) and specific challenges are derived as a consequence of these trends. Finally, changing logistics includes the following challenges: supply chain as a competitive advantage, manufacturing and process innovation, labour force, capacity shortage, co-modality, hybrid distribution structures, big data and the physical internet.

The major challenges for manufacturing companies are "aligning corporate strategy with the right organisational model and matching that strategy to targeted customer segments—by size, footprint, vertical category and market. Leading logistics providers excel at understanding key customers' needs and purchasing behaviours—and they know that understanding is a key ingredient to build a solid strategy and defining the most efficient commercial approach and offerings".[1] Other challenges can be related to (Gunasekaran et al. 2015): dependency on few suppliers, inability to react quickly to uncertainties, the nature of buyer-supplier relationships and the channel they choose to do transactions.

As one-size-fits-all approach does not work well especially in diverse global supply chains, in response to ever-changing business dynamics, the supply chain strategies need to be adapted to the characteristics of each industry. For example, the fashion industry is characterised by three critical lead-times (Christopher et al. 2004): time-to-market, time-to-serve, and time-to-react. These three factors stress the importance of agility and responsiveness in supply networks to meet customer needs. Some key aspects include (see Clausen et al. 2016): (1) better utilisation of existing infrastructures, (2) the difficulty in cost-effectively increasing capacity by physical infrastructure expansion in Europe, and (3) anticipated shortages in manpower required for physically demanding tasks.

Much progress has been made on large-scale modelling of complex supply chain design to make them responsive as well as efficient in different sectors. The objective is to design robust supply chains, i.e. with ability to cope with internal and external disruptions and disturbances. Research should focus on the relation of robustness, complexity and efficiency of supply chains to support management decisions (Monostori 2018). In addition, there still exists a great need for efficient approaches to deal with the multi-scale (modeling, optimisation, and uncertainty, especially as supply chains grow large and highly interconnected), multi-objective (development of better measures and models for a variety of economic, environmental, and social objectives), and multi-player challenges (implementing the concepts of competition, transfer prices, and contracts between a potentially distributed or decentralized network of supply chain players) of modern supply chains (Garcia and You 2015). In addition, in (international) supply chains, (Gold et al. 2015) argue that socially responsive policies require identifying and eliminating slave labour as a challenge that implies understanding its appearances, its financial and socio-cultural rationale and its stakes.

[1] https://www.bain.com/insights/challenges-and-winning-models-in-logistics.

Evidently, the identification of challenges for future supply chains should take into consideration related actions/decisions in global supply chains at all levels, ranging from efficient product design to socially responsible policies. (Simchi-Lev D et al. 2008) illustrates a typical supply chain, consisting of "*suppliers, manufacturing sites, warehouses, distribution centers, and retail outlets as well as raw materials, work-in-process inventory, and finished products that flow between the facilities*". Some of the challenges for such typical supply chains have been discussed above, and their identification is based on supply chain functional areas such as network planning, inventory control, supply contracts, distribution strategies, integration and strategic partnering, outsourcing & procurement strategies, and product design.

The above list of functional areas provides a starting point in the identification of challenges in this chapter, considering what the major decisions supply chain managers need to take although other decisional dimensions are also considered later (e.g., financial). In doing so, we specifically consider how the decisions regarding the challenges will be made in the future under the six macro scenarios (optimistic, pessimistic, intermediate).

3 Methodology

We employ a three-stage process to identify challenges and classify them into groups. The first stage consists of desk research and brainstorming sessions within partner organisations to identify an initial set of potential challenges under the aforementioned six macro scenarios (detailed scenarios narrative in Sardesai et al. 2020). Later, in the second stage, this list is validated by the industry stakeholders via a workshop with participants from different sectors. Then a clusterization of the challenges identified in stages 1 and 2 is performed in Stage 3. Below, more details regarding the methodology are provided:

Stage 1: Identification of specific challenges. Identification of specific challenges for the six macro-scenarios is performed based on the definition of the Supply Chain dimensions used to build the mapping of the characteristics of the future networks to scenarios features. Desk research and brainstorming sessions among different experts participating in the project led to the following general categories of the supply chain dimensions used for the identification of challenges:

- **Sourcing strategy**:
  - Local/Glocal/Global Sourcing.
  - Sourcing and Shoring Characteristics.
  - Localisation.
  - SC Structure.
- **Distribution:**
  - Inventory levels.

  - Distribution Characteristics.
  - Shipping Characteristics.
  - Structure Characteristics.
  - Transport Characteristics.
  - Environmental Impacts.

- **Supply chain integration:**
  - Material flow integration.
  - Information flow integration and IT infrastructure.
  - Financial flow integration.

- **Finance:**
  - Presence/absence of Intermediaries.
  - Currency Characteristics and Use.
  - Regulations.
  - Technologies.

Stage 2: Validation of specific challenges. A workshop was organized to validate the challenges identified in Stage 1 and ensure that they are relevant for the industry stakeholders and are grounded in reality. In addition to validation, some additional challenges/opportunities proposed by the industry experts were integrated into the list created in Stage 1. A description of the methodology used during the workshop sessions to encourage the participation and discussion is presented in detail in Sect. 5.4.2.

Stage 3: Clusterization of challenges. The challenges identified in stage 1 and the others added during the workshop were carefully analysed and clustered applying similarity criteria to arrive at a final list of challenges. Their nature and characteristics allowed us to identify 4 categories (i.e., Legal, Operational, Behavioural, Financial) based on macro-areas that will require similar actions to face the potential issues. Moreover, a fifth category was added in order to consider the technological challenges based on the mapping of technologies described in Stute et al. (2020).

4 Identifying Specific Challenges for Supply Chains of the Future

4.1 Identification of Specific Challenges from Macro-Scenarios

Each brainstorming session carried out was focused on a specific macro-scenario, considering the "actions/decisions" that supply chain managers should take under the conditions identified in Barros et al. (2020). Some examples

for such actions/decisions are: sourcing decisions (multiple/single, global/local, outsourcing/in-house), setting inventory levels, network design (e.g., centralized versus decentralized, facility location decisions), reverse logistics operations, distribution, delivery (e.g., long haul, last mile), information sharing and/or collaboration among supply chain partners.

The in-depth analysis of the six macro scenarios produced a list of 65 challenges (see Appendix 1). We observed that there are some common characteristics among the 6 macro scenarios and therefore, concluded that in several cases firms could face similar challenges in very distinct future scenarios. For instance, the necessity of carrying higher inventory levels seems to be a challenge when "protectionism" leads to shorter supply chains in general but requires companies to spend more time at border crossings and complete necessary import/export paperwork. Similarly, the same challenge appears to be relevant when global trade is facilitated without complicated paperwork, but lead times are still large as firms source from far away suppliers if it makes economic sense. Consequently, certain challenges are quite important regardless of how the future looks like and businesses need to come up with sound strategies mitigating risks stemming from such challenges. Most probably, "proactive" strategies must be designed for them as the total likelihood of these multiple scenarios being realized is significant. Contingency planning or a mix of proactive and contingency planning might be the appropriate choice for some other challenges that only appear in rare situations (e.g., only one future scenario).

Another observation coming from this first set of challenges is that a large number of them are relevant for scenarios that are deemed to be "more positive (optimistic)" in the sense that countries across the globe keep cooperating, international trade grows under the presence of political stability and well established alliances (e.g., PrOCEEDINg and aSPIRANT). Although this might sound counter-intuitive at first sight, it also makes sense as the supply chains get larger and more complicated (due to the existence of heterogeneous systems most likely with decentralized decision making) when global operations become the norm. In other, more pessimistic scenarios (e.g., protectionism), supply chains might become more local which creates its own challenges, however at the same time leads to "simpler" chains to manage in general.

4.2 Validation of Challenges with Industry

Analysing the challenges collected, we observed that often they have different relevance according to specific roles and actors in the SC. For example, it is clear that future scenarios leading to more "local sourcing" due to protectionism might create a "challenge" for "buyers" of raw materials/products as there are fewer suppliers (only local) to choose from. This, however, might be an "opportunity" for "local suppliers" in the sense that they now would have more power (e.g., can charge higher prices) and even develop local networks. Consequently, for all the actors within a supply chain

to survive in different future scenarios, a holistic view needs to be taken and win-win solutions have to be designed. For this reason, the stage 2 should also consider whether a certain trend creates a challenge or not depending on "what supply chain actor" one looks at.

In this stage, a group of experts was invited to participate in a workshop organized at the Zaragoza Logistics Center to validate the challenges for the Supply Chain under the six macro-scenarios. The group of experts (15 people) involved has different but selected professional backgrounds and a specific capability on the topic of interest and it includes (as recommended by Krueger and Casey 2015): (1) Industry stakeholders: participants with relevant positions within companies from the process industry, distribution logistics, and discrete manufacturing. More specifically the following industries were represented: steel, petrochemical, consultancy, engineering, and Fast-Moving Consumer Goods (FMCG); (2) academia: participants from academic institutes or research departments within companies. The majority of the participants represented the industry perspective. During the workshop, the participants were divided into three groups to facilitate the face-to-face discussion; the interaction among members in the same physical space in an open-minded, undirected atmosphere facilitating the generation of fast-result insights (Zeng et al. 2019). Each group analysed the challenges, presented in Appendix 1, of two different scenarios The methodology used, comprising three steps, in this second stage is described below, followed by the summary of the results obtained. The challenges proposed in Sect. 5.4.1 were validated and additional challenges were identified during the workshop.

The three steps of the workshop are:

- Step 1: Ensuring that each participant works on "two different macro-scenarios. The matching between participants and the scenarios were made such that each participant works on scenarios that are as "dissimilar as possible" (e.g., pessimistic and optimistic). It was guaranteed that each scenario was discussed by a team at least once during the workshop.
- Step 2: In order to "facilitate" the process of identifying potential challenges, a setting where different participants assumed different roles (i.e., Supplier, Buyer, Policy Maker) was chosen. Finally, in order to close the loop and remind the participants that the "reverse logistics" topic is also critical, a role called the "Circular Economy (CE) facilitator" was assumed by some participants. These roles were described to the participants before the workshop (reminding them that a particular entity—e.g., government—can assume all of the above roles in different supply chains). Once each participant contemplated the challenges on her/his particular role, they were asked to discuss the "Supply Chain Coordination/Integration" issues as a "team". We observe that this "role playing" facilitated the discussion and interesting results emerged in the end. In summary, for each scenario, the following roles were assumed by the different participants in a given team: Supplier, Buyer, Policy maker, Circular Economy (CE) Facilitator. SC Coordination role was assumed by all participants together in a given team. The following activities were performed by each team:

  - "All participants as a group" would discuss the overall implications of the "scenario" (10 min) to make sure everyone is on the same page.
  - "Each individual participant with the determined role" would contemplate what challenges/opportunities would arise under the particular scenario and place them on the board using post-its (10 min).
  - "All participants as a group" would discuss together the SC issues (integration, links between different roles, etc. under the guidance of the SC Coordinator) and come up with SC related challenges/opportunities (10 min).
  - "The team" would summarize the challenges/opportunities on a different sheet of paper (5 min).
- Step 3: All the challenges from different scenarios are discussed by all participants at the end of the workshop.

As a result of the workshop some common challenges were identified along the six scenarios:

- From the point of view of the supplier, the main challenge is how to be competitive and to gain or maintain market share. One possible strategy is through differentiation, e.g. through technology or the use of new materials (linked to challenges #5 and #6, see Appendix 1).
- The main challenges for the buyer are the adaptation to new business models according to the new technology selected (linked to challenge #1, see Appendix 1) and the existence of policies that promote sustainability.
- For the policy maker, the main challenge is to establish the suitable environmental laws, making use of the proper channels to share the information (linked to challenge #11, see Appendix 1).
- The facilitator faces the legislative pressure on the final disposal of goods. Different technologies can bring a detriment to the use of human labour leading to a loss of employment. In addition, digitalisation (at different levels) can be used for the circular economy coordination to create new jobs. This poses a challenge due to data protection issues (linked to challenge #5, see Appendix 1).

A list of challenges for the Supplier, Buyer, Policy Maker and Facilitator (roles assumed by the participants) defined during the workshop in every scenario was identified. In addition, workshop participants confirmed that the challenges identified in Stage 1 are practically relevant, but additional challenges were identified (see Appendix 2).

4.3 Clusterization of Challenges for Supply Chains of the Future

In this stage challenges derived from the desk research and validated by industry experts via the workshop are clustered in several groups. As the list was extensive,

a deeper analysis was conducted to find similarities and cluster the challenges highlighting the most important topics (based on qualitative evaluation of the reason put forward by the expert when identifying a challenge). The aim of such clusterization is to help managers to understand the origin of these challenges, capture the major/recurring common themes, and hence focus their efforts in facing them. The clusterization of the challenges is based on the comparative analysis of the content provided by stages 1 and 2 and grouping is based on similarities in the concepts expressed by each challenge (see Table 1).

Due to the recent advances in technologies for product design, manufacturing, information, transportation with the significant potential to shape the future of

Table 1 Supply Chain Specific Challenges from clustering of stage 1 and stage 2 results

Challenge # and Definition
SCH #1 Developing new collaborative SC models
– Developing new business models to encourage coordination/collaboration maintaining information symmetry across different SC entities for end-to-end SC solutions with the ultimate goal of matching supply and demand and creating agile/responsive SCs (CH #1) – Lack of willingness to share information (CH #64) – Managing power differences to avoid inefficiencies along the SC (CH #68) – Ease supplier-buyer financial relationship (CH #72)
SCH #2 Resource management for a circular economy
– Need for more efficient (and holistic) manufacturing, collection, recovery, disposal, recycle, reuse (CH #2) – Ensuring quality of the goods produced with recycled materials (CH #2) – Management of the "growing product portfolio" with the new (recycled) goods (CH #2) – Designing of new materials with longer lifecycle (to be used multiple times) (CH #2) – Incentivizing Industrial symbiosis practices for resource sharing (CH #2) – Developing governments incentives (rewards/penalties) to make circular economy financially attractive (CH #2) – Managing additional complexity dealing with new regulations and incentives (penalty/reward) from each country (government) for more reuse/recycling (CH #29) – Creating standard/harmonized waste management and environmental impact measurement processes (CH #30)
SCH #3 Sourcing complexity management
– Dealing with increased average lead time and uncertainty and complexity of managing suppliers (CH #3) – Managing a larger supplier base located in different parts of the world with different conditions, regulations, etc. (CH #12)
SCH #4 Developing "Leaner" and more flexible SC
– Maintaining high service level and quick response time (higher inventory levels); Striving to eliminate redundant resources and working capital and managing the risk of obsolescence (duplicate stock and assets) (CH #4) – Having a flexible responsive SC (via proactive procurement, Just In Time delivery/replenishment, on-demand forecasting) (CH #39) – Service assurance (CH74)

(continued)

Table 1 (continued)

Challenge # and Definition
SCH #5 Promoting efficient and sustainable logistics in urban environment
– Developing of autonomous and environmentally friendly last mile logistics systems in urban environments (dealing with problems with wrong addresses, personalized shipping) (CH #5) – Improving use of location technologies and optimisation of routes (CH #5) – Being able to manage "centralized" distribution centers in smart cities, in terms of lack of IT dyinfrastructure, delivery costs, and risk management (CH #25) – Integrating of rural and urban areas (CH #84) – Integratingdistribution with proximity delivery points in urban areas (CH #86)
SCH #6 Facing changes in SC due to personalised shipment
– Managing the growing cost of delivery/pickup and smart management of added packaging complexity due to personalized shipping (e.g., size, package, confidential information, lack of bundling opportunities) (CH #6) – Increasing use of smart materials for packaging design (CH #6) – Changing SC structure due to disintermediation of some players in the SC (CH #6)
SCH #7 Organizing SC for variable and custom demand
– Understanding customer demand; need for developments in gathering huge volumes of data from customers and handling it, (CH #7) – Building an agile network to respond to this customer demand (deal with larger product variety, variability and customized products) (CH #7) – Getting closer to the final customers by establishing, fablabs, hotspots and service centers and postpone "last" activities to these centers to deal with customisation (CH #36) – Dealing with shrinking customer market (CH #42) – Dealing with larger price sensitivity (CH #48) – Ensuring sufficient amount of raw materials given long lead times to cope with increased demand (aspirant) (CH #49) – Problems in addressing market needs (CH #71) – Balance customisation needs with shorter SCs (CH #85)
SCH #8 Ensuring quality along the SC
– Ensuring short delivery times, reliability, and quality (versus price) as they become much more important as competitive factors when consumers make purchasing decisions (CH #8) – Managing difficulties in quality control and standardization in global SCs (CH #8) – Ensuring quality standards to protect brand image and avoid financial penalties (CH #31)
SCH #9 Identifying talents in SC
– Developing new skills for digitalisation (CH #9) – Creating new training methods and apply new technologies in training (CH #9) – Defining an EU framework on SC Competences (CH #9) – Creating specialised and skilled workforce (CH #I)
SCH #10 Energy and emissions management
– Containing carbon emissions to stop increased pollution (CH #10) – Managing the increased use of electric vehicles to better use depleting natural resources and reduced energy consumption finding alternative energy sources (CH #10)
SCH #11 IT integration and interoperability

(continued)

Table 1 (continued)

Challenge # and Definition
– Setting up standardized data processes and integrated IT infrastructure (CH #11) – Maintaining secure IT infrastructure (CH #11) – Integration of heterogeneous devices and applications (CH #11) – Need for Simplified SC administration and too much dependence on IT (CH #37)
SCH #12 Managing ip protection issues
– Dealing with IP Rights issues (CH #13)
SCH #13 Dealing with digital-driven issues
– IT Platform Management (CH #14) – Cyber Security Issues (CH #14) – New Business Models Creation (such as centralized sourcing for multiple DIY manufacturers through an online platform) (CH #14) – Online and real-time track-and-trace solutions for smart materials management with multiple locations (even including the customers who become prosumers with the DIY) (CH #15) – High performance of automated logistics systems (CH #54) – Sustained support for new product development technologies, integrating them with legacy systems (CH #56)
SCH #14 Human perspective in digital transformation
– Technology development (automation) and Change Management (automation versus human) (CH #16) – Human centered approach in developing equipment (mobile apps, smart contracts, etc.) and more training environments for "digital transformation officers" (CH #16)
SCH #15 Coping with digitalisation and globalisation in finance
– Implementing blockchain technology to develop trust among SC partners and financial/bill settlement models in SCs (CH #17) – Using alternative currencies (CH #17) – Creating profiles who can manage these complementary currencies and seamless payments with the customer data protected (CH #17) – Managing global supply agreements with multiple currencies with suppliers/customers in multiple countries (CH #18) – New business models for fintech collaboration (CH #21) – Regulating competition between centralized banking systems and FinTech (CH #58)
SCH #16 Addressing problems and limitations of regulatory framework
– Dealing with increased cost of resources because of trade barriers (CH #19) – Creating the adequate legal and regulatory framework for financial flow reducing the complexity of financial transactions and compliance costs with international regulations (aspirant) (CH #27) – Dealing with tax related additional workload and cost (CH #28) – Legal and compliance issues (CH #43) – Developing new laws to regulate and simplify the access to finance founds (CH #60) – Dealing with an informal "parallel" economy due to lack/ambiguous regulations (CH #70) – Aligning legislation according with technology (CH #83)

(continued)

Table 1 (continued)

Challenge # and Definition
SCH #17 Facing outsourcing complexity
– Dealing with loss of jobs (social) (CH #22) – Increased dependence on third party capacity (CH #23) – Dealing with the negative effect of outsourcing on R&D development at home country (CH #33) – Dealing with the risk of not being able to reduce costs via outsourcing (CH #50) – Coordinating outsourcing and nearshoring (CH #61)
SCH #18 Managing omnichannel SC and multimodality
– Managing omnichannel supply chain strategies (CH #26) – Being able to efficiently use multimodal distribution ensuring product integrity and to reconfigure based on demand evolution (CH #34)
SCH #19 Managing complex or increased information flow
– Leaking confidential information (CH #32) – Being able to control the quality of information from the extensive use of algorithms for distribution optimisation (CH #35) – Less asset control and more data control for revenue streams (CH #38) – Making sure that security is ensured in the SC (CH #40) – Increasing cyber-security of private data related to product personalisation and customer profiling (CH #59) – Using suitable channels to share information along the SC (CH #80)
SCH #20 Dealing with industry concentration and competition
– Dealing with the negative impact of industry concentration on production growth, due to the higher level of market entry, product variety, and geographic concentration of production networks (CH #51) – Anti-trust risks arising from concentration of manufacturing competition in Europe and US (CH #52) – Competing for resources and infrastructure to establish presence in growing economies (CH #62) – Supporting SMEs to stay in the market (CH #63) – Dealing with more competitors and mapping them with observatory (CH #65) – Loss of competitiveness compared to Asia (CH #75) – Empowering public administration to regulate strong partnership agreements (CH #78)
SCH #21 Managing risk and disruption
– Risk management in global SCs (unethical activities such as child labor, disruptions, strikes, disasters, etc.) (CH #24) – Being able to manage disruptions/disasters (CH #55) – Overcoming rigidity and lacking of reactivity towards unexpected events (CH #67)
SCH #22 Facing inventory and shipping problems
– Dealing with low variety of inventory in different hubs/DCs/Warehouses (CH #46) – Finding drivers (CH #47) – Dealing with the increased costs of shipping and risk of product stock outs (CH #53) – Need to centralize inventories and distribution, at least for the parts and components in urban areas (CH #57) – Using autonomous vehicles extensively and integrate those into the existing processes (CH #45)

(continued)

Table 1 (continued)

Challenge # and Definition
SCH #23 Policies
– Setting trade policies (CH #69) – Political uncertainty impacting investments (CH #73) – Setting flexible tax policies (CH #76) and economic/social policies for new markets (CH #77) – Considering to take under control environmental damage due to increased pollution and waste (CH #81) – Overcoming innovation inertia (CH #87) – Targeting inclusive policies to contrast unemployment and social inequality (CH #88) – Need of an independent observatory on the role of EU in international SCs (CH #41)

supply chains, we opted to identify the technological challenges separately and later added them to the previous set of 65 challenges. Eighteen enabling technologies (see Stute et al. 2020) were identified (i.e. Autonomous Transport Systems; Robots; Cloud Based Computer Systems; Internet of Things; Distributed Ledger/Blockchain; Artificial Intelligence; Data Science; Mobile and Wearable Devices; Communication Infrastructure; Identification Technologies; Location Technologies; Visual Computing; Additive Manufacturing; Energy Infrastructure; Alternative Propulsion Systems; Renewable Energy Technologies for Production and Storage; Smart Materials; Nanotechnology). A careful analysis of the gaps and implementation challenges of such enabling technologies resulted in a list of thirteen technological challenges, which are transversally linked to the challenges presented in Table 1, and it is provided below:

- TCH #1: *Lack of technology maturity and/or underdevelopment of technology*. This challenge is related to the necessity to further develop existing or create new technologies and it emerged in areas such as positioning algorithms, connectivity, solve unexpected systems failures, extension of data network, data processing, data analytics and data sharing.
- TCH #2: *Improvement of energy systems and development of new power sources.* This challenge is mainly related to the current short/limited battery life to be used for different technologies (e.g. mobile and wearable devices, alternative propulsion systems, technologies for visual computing, robots). In addition, new power sources will be decisive for robots, and power supply and endurance in drones.
- TCH #3: *High cost of development and implementation of technology.* the high costs of devices are limiting the applicability of technologies like Location systems and IoT. Management cost is essential in Cloud Based Computer systems. High implementation costs are also affecting Artificial Intelligence and Additive Manufacturing systems (due to costs of 3D printing and smart materials).
- TCH #4: *Acceptance and awareness.* Increasing the acceptance level and awareness of technology impact on enterprises, culture and society is a preliminary step needed for the implementation of technology and at the same time a challenge.

- TCH #5: *Lack of standardization*: the lack of standardization and regulations is causing problems in artificial intelligence. The development of standards will be necessary/decisive for the following technologies: autonomous transport systems, visual computing, artificial intelligence, distributed ledger/blockchain, data science, alternative propulsion systems, location technologies robots, IoT, additive manufacturing, and energy infrastructure.
- TCH #6: *Safety for users*: safety is an important challenge in the implementation of technologies such as robots and Autonomous Transport Systems due to the presence of humans in the surroundings.
- TCH #7: *Data security and intellectual property threat*: data security, vulnerability and cybersecurity problems. Hacking can affect technologies such as data science, distributed ledger/blockchain, visual computing, cloud based computer systems, artificial intelligence, and energy infrastructure.
- TCH #8: *Scarce interoperability and difficulties in integration*: interoperability has to be increased for devices and integrated into the business processes (in IoT systems) and existing infrastructure, systems and production and supply chains (in smart materials and nanotechnology). For alternative propulsion systems this challenge is related to the limited existing models and refuelling infrastructure, workshop and service network.
- TCH #9: *Need for specialised workforce*: due to the continuous development of technologies, specialised workforce is needed for the effective implementation in areas such as Artificial Intelligence, blockchain technology (mainly related to IT and legislation), and smart materials (expertise in multiple disciplines for the conception and design of new solutions).
- TCH #10: *Limited production/scalability*: this challenge is mainly linked to the following technologies: mass production in nanotechnology, number of transactions in a distributed ledger/blockchain, augmented reality (currently a predominately mobile-focused technology), business scalability in renewable energy technologies for production and storage, and cloud-based computer systems.
- TCH #11: *Limited reliability*: this is a challenge directly related with the implementation of some technologies. In fact, it should be improved in Cloud Based Computer Systems, IoT (sensor's reliability has to be increased), and Additive Manufacturing (printing of complex parts in 3D printing) among others.
- TCH #12: *Technology accuracy*: different types of technologies need to improve their accuracy for implementation. For example, location technologies (location accuracy), mobile and wearable devices (data accuracy), visual computing technology, and identification technologies (RFID sensors sensitive to environmental conditions).
- TCH #13: *Feedstock supply*: feedstock supply can be limited depending on raw materials. In addition, some rare and scarce materials are used as core elements in the development of alternative propulsions systems (e.g. lithium-ion batteries for electric vehicles). The use of rare materials also limits the implementation of smart materials.

Appendix 3 shows which technological challenges are relevant for the 18 enabling technologies identified for future supply chains.

A careful analysis of the reasons why these challenges are relevant leads to the observation that while some are technological/infrastructure related, some others could be solely due to operational, behavioural, financial, and legal issues. In certain cases for example, even though the actors within a specific supply chain can effectively and efficiently share information (i.e., ICT is sufficiently developed and the systems enabling efficient data/information transfer are well established), they end up withholding critical information from their supply chain partners. This could be due to several reasons such as conflicting incentives, no legal requirement for such reporting or information sharing, the fear of releasing confidential information, or the risk of letting competition get their hands on such information (or even "create" own competition). It is important to keep in consideration this set of challenges to understand which kind of future problem companies and supply chain could face and therefore enable them to design and implement actions to address these issues efficiently. The 23 challenges presented in Table 1 were thus categorized into 4 categories: operational, behavioural, legal and financial. It has to be underlined that this is not a "formal" categorisation, but an attempt to classify challenges so that the efforts to overcome them are focused properly because, in many cases, they involve a combination of interlinked operational, behavioural, technological, financial, and legal issues. In what follows, we briefly discuss these challenges within the aforementioned categories:

Operational Challenges Longer and more complex/global supply chains with different technical and information infrastructures make supply chain management even more difficult. Some major operational issues that supply chain managers regularly need to deal with are: supply chain configuration (i.e. sourcing and distribution decisions, facility location, shoring strategies), inventory planning, integrating forward and reverse flows, demand forecasting. Others are related to management and implementation of new technologies such as digital platforms or the integration of robotics in manufacturing and distribution environment (considering the interaction with workers), or to the tracking and tracing capabilities to enable actions based on unexpected deviations from the plan. To sum it up, challenges #1, 2, 3, 4, 5, 6, 7, 11, 13, 17, 18, 19, 20, 21 and 22. Therefore, significant research in improving the quality of such decisions must be carried out to be effectively and efficiently combat such challenges.

Behavioral Challenges In decentralized systems where each entity in the supply chain strives for optimizing its own objectives (e.g., maximizing profits) without considering the impact of own decisions on the performance of the rest of the partners, it is known that the system efficiency (of the whole chain) deteriorates. This is not only due to technical inefficiencies in data/information and resources sharing, but also, maybe to a larger extent in certain cases, due to lack of trust between supply chain partners. In general, it is quite difficult to change such behavior and make people adopt a holistic view of the supply chain rather than their own firm/business unit in isolation. Initiatives to increase coordination and collaboration among supply chain

partners are not always successful because of the lack of willingness to share information, coordinate actions, and collaborate when necessary, even if it is technically possible. Some collaborative business models, such as the Collaborative Planning and Forecasting Review (CPFR), have been used and shown to benefit parties involved. But, in many other examples, different players in a supply chain do not get involved in such collaboration/coordination initiatives because of not being able to evaluate the added benefits/costs and how these would be allocated. Other major reasons for this lack of interest in coordination are the fear of losing control (decision making), and the leaking of critical/confidential information which could be used against the firm (e.g., danger of disintermediation within its own supply chain, or the information being used by competition). Models that encourage trust building, incentivise parties to share truthful information (through penalty/reward mechanisms), fair allocation of added costs/benefits of collaborative actions, and horizontal/vertical coordination need to be investigated in detail. Management of cultural differences in global supply chains is also of utmost importance when it comes to behavioral issues. Last but not least, behavioral issues are apparently not limited to only collaboration/coordination among partners. With the recent trend for consumer-driven supply chains, it is of grave importance to "understand" how consumers react to the offers from the providers of products/services. Therefore, challenges in "understanding how consumers behave, purchase, consume" is also critical, and research in this direction is also required, especially models need to be developed to analyse complicated (and possibly irrational) consumer behaviors. Similarly, exploring the impact of consumption patterns on waste generation/recycling/reuse is one of the most promising future research directions, To sum it up, Challenges #1, 2, 3, 7, 9, 10, 11, 12, 14, 15, 16, 17 and 21, all have a behavioral component and require models that are "human-centric".

Legal Challenges Regardless of whether a supply chain is local or global, there are certain legal obligations that each supply chain actor must comply with. Apparently, this becomes a herculean task for firms that do business with worldwide supply chain partners. There are different and at times conflicting regulations in different parts of the world, and companies that are present globally need to develop effective strategies to ensure compliance. These challenges limit the options supply chain professionals have and determine the boundaries in which they can do business. Challenges #2, 3, 12, 13, 16, 19, 20 and 23, are particularly relevant.

Financial Challenges Recently some innovations have been introduced in the field of supply chain finance that have the potential to change the way businesses manage the financial flows such as crowdfunding, new forms of payments and cryptocurrencies. New research needs to be carried out to identify proper models to finance Small and Medium-Sized Enterprises (SMEs) as well as big players (e.g., reverse factoring, crowd-funding, platforms enabling the allocation of costs/benefits through smart payments and smooth financial transactions), explore the impact of new currencies on global trade agreements and the use of new technologies for financial flow integration and emergence of fintech providers. Challenges #11, 15 and partially 1 are quite relevant to financial issues in global supply chains.

Technological Challenges As technology continues to be a critical element in supply chain performance, and due to the recent advances affecting process industry, distribution and logistics, and discrete manufacturing, we performed a separate study based on eighteen enabling technologies (see Sect. 5.4.3). Thirteen additional challenges were identified. The mapping of technological challenges onto specific technologies (see Appendix 3) showed that six technologies present the majority of challenges: IoT, Visual Computing, Autonomous Transport Systems, Robots, AI, and Location Technologies.

5 Discussion and Conclusions

This chapter discusses the challenges that will be faced by supply chain managers in the near future, considering future scenarios based on different evolutions of political, economic, social, technological, legal, and environmental trends. The challenges presented in this chapter, validated by experts from industry, are practically relevant for process industry, logistics and discrete manufacturing sectors.

We found that in several cases firms end up facing similar challenges in very distinct future scenarios, possibly due to varying reasons, regardless of the nature of the scenario (i.e., whether it is a pessimistic or an optimistic scenario). However, some challenges turned out to be quite unique to certain future scenarios and perceived to be less likely to exist. We claim that this input would be of critical importance in the design of either proactive or reactive strategies (or a hybrid of the two) for firms.

We also present a classification of the identified challenges based on the emerging common themes into four dimensions: operational, behavioural, financial, and legal. This clustering provides the managers with a good guide in overcoming such challenges as it provides an easily navigable tool to identify which challenges are relevant and where they should focus their efforts. For example, if a particular challenge is stemming more from behavioural issues (e.g., lack of trust among supply chain partners), it would make more sense to attack this root cause before spending significant amount of money in Information Communication Technology (ICT) investments to boost reliable information exchange.

Regarding the recent technological advances, major gaps and related challenges were identified. Lack of maturity of technology or underdevelopment of technology, data security and intellectual property threat, and lack of standardization for the use of technology seem to emerge as the most common technological challenges related to the enabling technologies.

The results of this chapter serve as an essential basis for the development of a roadmap to strengthen the competitive position of the European Supply Chains in the process industry, logistics and discrete manufacturing sectors, as presented in Fornasiero et al. (2020).

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Appendix 1. Challenges for Macro Scenarios Identified in Stage 1 of the Methodology

Challenges
CH #1. Collaborative SC models
CH #2. Resource management for a circular economy
CH #3. Uncertainty and complexity management
CH #4. High service level in SC
CH #5. Efficient and sustainable transportation in urban environment
CH #6. Personalized shipment
CH #7. Customer knowledge
CH #8. Quality control along the SC
CH #9. Talents in SC
CH #10. Energy and emissions management
CH #11. Integration and interoperability
CH #12. Management of globalized suppliers
CH #13. IP protection
CH #14. Information in the cloud
CH #15. Real-time track-and-trace solutions
CH #16. Human perspective in digital transformation
CH #17. Use of alternative currencies
CH #18. Global supply agreements
CH #19. Trade barriers
CH #20. Location decision
CH #21. Fintech in the SC
CH #22. Loss of jobs
CH #23. External dependence

(continued)

(continued)

Challenges
CH #24. Risk management
CH #25. Distribution management in smart cities
CH #26. Omnichannel
CH #27. Financial regulatory framework
CH #28. Tax issues
CH #29. Increased complexity
CH #30. Waste management and environmental impact
CH #31. Quality assurance
CH #32. Information management
CH #33. R&D levels
CH #34. Efficient multimodal distribution
CH #35. Information quality
CH #36. Customisation
CH #37. Technology dependence
CH #38. Increased data control importance
CH #39. Flexible responsive SC availability
CH #40. Data security along the SC
CH #41. Suppliers monopolizing the market
CH #42. Customer market reduction
CH #43. Legal and compliance issues
CH #44. Knowledge development and supplier selection
CH #45. Adoption of autonomous vehicles along the SC
CH #46. Inventory variety reduction
CH #47. Shortage of drivers
CH #48. Price sensitivity
CH #49. Raw material availability
CH #50. Managing cost reduction via outsourcing
CH #51. Industry concentration and production growth
CH #52. Anti-trust risks
CH #53. Increasing costs of shipping
CH #54. Performance level management of automated logistics systems
CH #55. Disruptions management
CH #56. Integration of new product development technologies
CH #57. Centralisation of inventories and distribution
CH #58. Integration of traditional and new financial systems
CH #59. Cyber-security and customer profile
CH #60. Financial funds accessibility

(continued)

(continued)

Challenges
CH #61. Outsourcing-nearshoring balance
CH #62. Implantation in growing economies
CH #63. Survival of SMEs
CH #64. Information sharing
CH #65. Increasing EU competitiveness

Appendix 2. Additional Challenges Identified During the Workshop with Industry Stakeholders

Challenges
CH #66: Exploit climate issues as a marketing opportunity
CH #67: Rigidity towards unexpected events
CH #68: Manage power differences to avoid inefficiencies along the SC
CH #69: Set Trade policies
CH #70: Deal with an informal (parallel) economy
CH #71: Difficulties in addressing market needs
CH #72: Ease “SUPPLIER—BUYER” financial relationship
CH #73: Political uncertainty impacting investments
CH #74: Service assurance
CH #75: Loss of competiveness
CH #76: Application of flexible tax policies
CH #77: Set economic/social policies for new markets
CH #78: Empowering public administration to regulate strong partnership agreements
CH #79: Lack of international rules
CH #80: Use of suitable channels to share information along the SC
CH #81: Consider how to take under control environmental damage due to increased pollution and waste
CH #82: Economic stagnation
CH #83: Alignment of legislation according with technology
CH #84: Integration of rural and urban areas
CH #85: Balance customisation needs with shorter SCs
CH #86: Integrate distribution with proximity delivery points in urban areas
CH #87: Overcoming innovation inertia
CH #88: Target inclusive policies to contrast unemployment and social inequality
CH #89: Creativity in finding alternative supplying opportunities

Appendix 3. Mapping of Technological Challenges on Specific Technologies

	TCH #1	TCH #2	TCH #3	TCH #4	TCH #5	TCH #6	TCH #7	TCH #8	TCH #9	TCH #10	TCH #11	TCH #12	TCH #13
Autonomous Transport Systems	■	■		■	■	■	■	■					
Robots	■	■	■	■	■	■	■						
Cloud Based Computer Systems	■		■				■	■		■	■		
Internet of Things	■		■	■	■	■	■	■			■	■	
Distributed Ledger/ Blockchain	■	■		■	■		■			■			
Artificial Intelligence	■		■	■	■		■		■			■	
Data Science	■						■		■		■		
Mobile and Wearable Devices	■	■		■			■			■		■	
Communication Infrastructure	■						■				■		
Identification Technologies	■		■		■							■	
Location Technologies	■	■	■		■		■			■		■	
Visual Computing	■	■		■	■	■	■		■	■		■	
Additive Manufacturing	■				■		■				■		
Energy Infrastructure	■	■			■		■						
Alternative Propulsion Systems	■		■		■			■					■
Renewable Energy Technologies	■		■	■						■	■		
Smart Materials	■		■	■					■				■
Nanotechnology	■					■			■	■			

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