Lecture Notes in Management and Industrial Engineering

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Next Generation Supply Chains

A Roadmap for Research and Innovation

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Foreword

I have always subscribed to the view that the supply chain can provide a powerful platform for creating competitive advantage and that it can enable the business to differentiate itself in the marketplace.

The complexity and turbulence that increasingly characterises the business environment today requires supply chains to be adaptive and open to innovation in the face of unexpected challenges. More than ever, supply chain management has become a paramount strategic area to support companies, the economy and society as we seek to respond to those challenges.

We are witnessing a shift in organisations' priorities when it comes to supply chain design and strategy. Words such as resilience, visibility and flexibility feature in corporate policy statements and many programmes are underway to transform our capability to respond to unanticipated events. At the same time, in recognition of new consumption habits and demands, sustainability—and all the elements that enable it—and digital transformation—or industry 4.0—have been incorporated—to a greater or lesser extent—into many supply chains.

The pace of change has been so intense that it is a hard task trying to predict what the supply chain future will look like. Obviously, there is no such a thing as a common recipe to deal with all the current challenges and trends. In this sense, I believe that we have to continuously reflect on possible future scenarios and try to prepare to respond to them. This is exactly what this book is about!

For the past two years, I had been following the NEXT-NET project (https://nextnetproject.eu/) and it was no surprise to realise that this book can actually help supply chain managers, researchers and policy makers navigate in times of crisis. The book describes six possible macro-scenarios for supply chains in 2030, which give the opportunity for supply chain managers to prepare for various future settings. It formalizes ten supply chain strategies with the related research and innovation priorities as a guide for academia and industry for their development and implementation. I particularly appreciate that this book also gives the perspective of eight industrial sectors, setting the research in specific contexts. Finally, the book proposes concrete policy actions to support companies dealing with their current supply chains challenges. I hope that readers will derive as much value as I have from the insights contained within this work.

Martin Christopher
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Preface

The year 2020 was characterized by a series of sudden changes that have already heavily affected the economy and the whole society worldwide and are expected to have serious long-lasting consequences in the years to come. After the initial shock for such disruptive event and after the immediate focus on the management of the health crisis/emergency, the world is looking at the consequences of the pandemic caused by COVID-19. The containment measures and the limitations, put in place in each country necessary to save lives and not further overload the national healthcare systems, have had a devastating impact on the worldwide economy and trade since several sectors of national economies were shut down, including many services (hotels, restaurants, non-essential retail trade, tourism) and significant shares of manufacturing. Production and trade registered falls more steeply in sectors characterized by complex value chains, as for electronics and automotive products. With these conditions, managing supply chain disruption is a challenge for both global and local enterprises as it requires striking a balance between containing the pandemic on the one hand and keeping the economy going on the other hand.

A lot has changed since the conception of this book demonstrating once more the rapidly changing nature and interconnectedness of modern economies. This book has become even more necessary than when it was conceived since academia and industry are asked to understand how companies can significantly adapt the way they are organised and interlinked within their Supply Chains (SC) and to propose concrete actions. At the beginning of our study, we were focusing on understanding how trends like customisation, climate changes, scarcity of resources, acceleration of the technological development bring threats and opportunities for manufacturing sectors (particularly in Europe), as well as for the distribution and logistics sectors and lead to the need of new and reconfigured SCs that shift from cost competitiveness to striving for the highest value. The importance of forecasting and face up to exogenous factors on SC is more than ever before under our eyes in this period of pandemic disaster.

New technologies especially related to digitalisation are changing not only the way companies produce and distribute, but also the relationships in networks. Some important themes emerging in these last months enabled by new manufacturing and distribution technologies are even more urgent like: containerized production and last mile delivery of customised and emergency products; management of manufacturing activities in mini-factories by service providers; reuse and recycling activities to recover second hand raw materials according to the circular economy paradigm; and drones/electric vehicles to change the way products are distributed. All these require a new vision on SC where research and innovation can play a key role for facing internal and external challenges to SC. The goals of this book are summarised as follows:

- To map trends and megatrends at political, economic, social, technological, legal and environmental level;
- To define industrial scenarios for the next decade based on the analysed trends;
- To understand how these scenarios may impact SC processes and how to design future SCs to answer the specific challenges;
- To map and analyse the enabling technologies for SC;
- To develop a roadmap for the full implementation of the proposed SC models based on research and innovation priorities identified for each future scenario, towards the full integration of production and distribution processes.

The content described in the book is based on a methodological framework that integrates top-down and bottom-up approaches by combining the application of future scenario building with the involvement of many stakeholders from different communities and sectors by means like surveys, interviews, brainstorming sessions and experts workshops. Case studies from process industry, discrete manufacturing, distribution and logistics, ICT providers are carried out to help further understanding the way SCs are changing and how they can improve thanks to innovation in sectors such as automotive, consumer goods, machine tools, chemical and steel.

The book is the result of the EU-funded Coordination and Support Action “Next generation technologies for networked Europe” (NEXT NET project-GA N.76884) with the aim to create a cross sectoral initiative at European level to increase integration between process, manufacturing and distribution sectors, proposing research and innovation priorities for the future supply chains. The partners of the NEXT NET project are: CNR, Aston University, Fraunhofer IML, INESC TEC, PNO Innovation, ZLC.

Milan, Italy — Rosanna Fornasiero
Dortmund, Germany — Saskia Sardesai
Porto, Portugal — Ana Cristina Barros
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First and foremost, our gratitude goes to all our co-author friends who embarked with us in the NEXT-NET project and in this exploratory journey with competences in the field of economics, management and industrial engineering, production engineering and social science to cover different aspects of supply chain studies. With their knowledge and experience it was possible to create an insightful book that otherwise would not be possible. A special thank goes to Irene Marchiori for her precious work both during the project and in the editing and preparation of this book.

The editors gratefully acknowledge the more than 150 experts from industry and academia involved along the project and supporting our work during the two-year experience with active participation to workshops, focus groups, questionnaires and surveys and all the steps we have put in place to arrive to the roadmap. The book has benefited immensely from their visions, valuable comments and suggestions during consultation and validation of the content.

Last but not least, we would like to sincerely thank the European Commission for the funding of the NEXT NET project within the Horizon 2020 work programme (DG Research) and in particular we would like to thank our project officer, Nicholas Delyanakis, for his support and valuable advice during the 2 years of the project.

Rosanna Fornasiero
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Executive Summary

The book incorporates applied research, concepts, and practical experience collected along the 2 years of the NEXT-NET project and is here organized in 10 chapters that have been grouped into three different parts. Part One focuses on the identification of the trends and related industrial scenarios for the next decade and the analysis of the implications for the Supply Chain (SC) processes and the consequent challenges. Part Two identifies the enabling technologies for SCs and maps these technologies to the SCs characteristics to understand where it is more appropriate to use these technologies. Finally, Part Three presents the roadmap for future SCs proposing 10 SCs strategies and the related research and innovation priorities for the full integration of the production and distribution processes; moreover, in this part policy recommendations are provided to support companies facing cross-sectorial and horizontal issues through suitable policy actions. This book is intended and designed for abroad audience that includes practitioners and managers, as well as academics and scientists interested to investigate future scenarios, collaboration mechanisms, and technology scouting for innovation throughout the supply chain.[1]

Part One: Trends, Scenarios and Challenges for Future Supply Chains

The first chapter "Megatrends and Trends Shaping Supply Chain Innovation" presents major megatrends and trends identified along Political, Economic, Social, Technological, Legal, and Environmental (PESTLE) dimensions through a systematic literature review and an experts' workshop. Companies operate in a macro-environment that is changing considerably due to large, transformative global forces. The wave of these megatrends and trends generates new prospects as well as challenges for the future of SCs and can be used to generate future SC scenarios.

[1]The authors are the sole responsible persons for the research work described in this book. EC is not liable for any use that may be done of the information contained therein.

The second chapter, "A Methodology for Future Scenario Planning", starts from the assumption that to build future visions and prepare companies and institution in developing innovative strategies, it is necessary to consider different possible scenarios as a forecast of possible developments of future. In the chapter, it is explained the methodology implemented to generate the industrial macro scenarios starting from the identified trends showing what the surroundings for supply chains might be like in a time horizon of ten years. The methodological framework is based on generating scenarios using a combination of quantitative and qualitative scenario planning methodologies. Close coordination and collaboration between production and logistics guides the underlying scenario design to focus the context on supply chains.

Chapter "Future Scenario Settings for Supply Chains" describes the six macro scenarios ranging from scenarios with progressive developments where all the PESTLE dimensions seems to be favourable to SC development to regressing or stagnating evolutions. Each of them is shaped by various socio-economic, political, technological and environmental developments.

Chapter four "Scenario-Driven Supply Chain Charaterization Using a Multi-Dimensional Approach" focuses on describing the characteristics of the SC in each of the six macro-scenarios by following the final stage of the scenario building methodology. SCs for each scenario are characterized in eight dimensions: Products and Services, Supply Chain Paradigm, Sourcing and Distribution, Technology Level, Supply Chain Configuration, Manufacturing Systems, Sales Channel, and Sustainability. This helps to understand the SC characteristics for possible future scenarios, in order to know how to respond to threats and take advantage of the opportunities that the next years will bring.

The threats and the opportunities are discussed in detail in chapter five "Unveiling the Challenges of Future Supply Chains: An Explorative Analysis" that focuses on the identification of challenges that SCs will most likely face. A preliminary list, obtained from the deep analysis of the macro-scenarios, was validated based on the input from industry stakeholders to assure practical relevance and grounded in reality. The 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.

Part Two: Enabling Technologies for Future Supply Chains

Technologies such as robotics, artificial intelligence, autonomous transport systems, data science, and additive manufacturing, among others, are gradually becoming part of people's and companies' daily lives and are changing the manufacturing, process industry and logistics sectors. In the first chapter of second part, "Technology Scouting to Accelerate Innovation in Supply Chain", the most important enabling technologies for supply chains until 2030 are identified and selected using a technology scouting approach and their implications on future supply chains are evaluated using an assessment methodology with different evaluation criteria. Although recent attempts have been made to understand the implications of these technologies on SC management, the relevance of the different technologies in future scenarios is still to be studied. Therefore, the second chapter "Mapping Enabling Technologies for Supply Chains with Future Scenarios" aims to fill this gap by presenting a technology mapping of enabling technologies based on technology portfolio approach, expert elicitation and literature. The final outcome is the mapping of the enabling technologies to the characteristics of the future European supply chain scenarios as a valuable tool for practitioners and researchers for the design and management of SCs.

Part Three: New Pathways to Future Supply Chains

The first chapter "Paths to Innovation in Supply Chains: The Landscape of Future Research" is the result of an intensive work jointly performed by a wide network of stakeholders from discrete manufacturing, process industry and logistics sectors who put forward a vision to strengthen European Supply Chains for the next decade. A detailed description of the 10 SC strategies identified as most relevant for next decade is presented with the related research and innovation topics as future developments and steps for the full implementation of the strategies proposing innovative and cutting-edge actions to be implemented based on technological and organisational developments (Fig. 1).

Fig. 1 Overall NEXT-NET framework and related components

Aiming to investigate the effective implementation of new SC strategies the second chapter of the third part, "A Journey into the European Supply Chains: Key Industries and Best Practices" provides a study of multiple cases of excellence among European SCs. It depicts an overview of major structural features of eight key industries for European economy, i.e. Automotive, Aerospace, Fashion, Chemical, IT, Distribution/logistics, Furniture, Food and Beverage analysing structure of the SC and companies. For each industry, case studies were carried out involving well-known companies and a cross-case analysis is reported.

Finally, the third chapter "Policy Recommendations for Supporting Supply Chains with Horizontal Actions" aims to identify the SC key horizontal issues, as they are cross–sectorial and faced by most companies operating both in production and distribution sectors. The chapter proposes a set of policy recommendations that can support public and private organisations to promote and foster innovation and competitiveness of future European SCs, regarding infrastructure requirements, technological and organisational improvements and regulatory developments needed to set the stage for the European SC for the future.

Contents

Trends, Scenarios and Challenges for Future Supply Chains

Megatrends and Trends Shaping Supply Chain Innovation

Dimitra Kalaitzi, Aristides Matopoulos, Rosanna Fornasiero, Saskia Sardesai, Ana Cristina Barros, Sébastien Balech, and Victoria Muerza

Abstract Companies operate in a macro-environment that is changing considerably due to large, transformative global forces namely megatrends and trends. The wave of these megatrends and trends generates new prospects as well as challenges for the future of supply chains. This chapter provides a review of 23 major megatrends and 72 trends identified in multiple dimensions along Political, Economic, Social,

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Technological, Legal, and Environmental (PESTLE) dimensions. The results are based on a systematic literature review and an experts' workshop, and can be used to generate future supply chain scenarios.

Keywords Megatrends · Trends · PESTLE analysis · Logistics · Supply chain management · Supply chain scenarios

1 Introduction

Megatrends are "large social, economic, political and technological changes [that] are slow to form, and once in place, they influence us for some time" (Kotler 2002, p. 137). Trends, as an indication into a direction of change, are driven by megatrends. For example, aging population is a megatrend and some of its trends are buying habits, and workforce gaps. Megatrends are observed over decades (15 + years) and affect almost all world regions while trends are observed over 5–10 years on specific parts of the world (Pictet asset management 2017).

Megatrends (e.g. new digital technologies) have a heavy influence on supply chains and they could impact product, process and network configuration (e.g. Calatayud et al. 2019; Birkel and Hartmann 2019). For example, blockchain technology (which is a trend) could lead to transparency, but it could disrupt the structure of supply chains as some intermediaries may have to be removed and the supply chain finance (Wang et al. 2019). Supply chain finance solutions can also be reshaped and boosted by the use of other technological trends e.g. artificial intelligence, internet of things, and big data analytics (Caniato et al. 2019).

Given the presence of these technologies, the role and relevance of supply chain governance mechanisms will be affected; e.g. digital transformation impacts on supply chain collaboration and integration (Barbieri et al. 2019). Companies have to develop a thorough understanding of these changes to avoid unexpected and negative effects and concurrently create opportunities to ensure long term survival. Future scenarios and hypotheses can be developed that will explore about how specific industries might evolve (Gernandt 2012).

There are numerous studies (e.g. Gernandt 2012; Seppälä 2016) that have identified several megatrends and trends such as electric vehicles, efficient multi-modal networks (e.g. Speranza et al. 2018), knowledge based development to talent management (e.g. Bowersox et al. 2000; Stank et al. 2015; Sweeney 2013), additive manufacturing and information systems (Fawcett and Waller 2014; Kemppainen and Vepsäläinen 2003). There is a lack of state of the art and comprehensive review of the list of megatrends and associated trends in the field of supply chain management and logistics. Apart from the studies mentioned above, consulting firms such as EY, PWC and KPMG have explored megatrends by frequently mentioning demographic shifts, geopolitical changes and environmental impacts as key megatrends. These studies lack comprehensive and coherent understanding of megatrends with political, economic or social megatrends being the center of attention (Malik and Janowska 2018).

Thus, the motivation of this study is to identify and verify systematically which megatrends are considered the most influential in this field by researchers and professionals. The purpose of this chapter is to recognize and increase knowledge of the megatrends shaping the future of supply chains and provide a comprehensive list of trends that addresses critical dimensions e.g. political, technological, environmental, and others. Through a systematic literature review, the following research questions intend to be answered in this chapter:

RQ1: "What are the megatrends shaping the future of the supply chains?"

RQ2: "What are the trends that can be derived from these megatrends shaping the future of supply chains?"

From a managerial perspective, this analysis allows companies to build a long-term supply chain strategy that is proactive, rather than reactive, by having a thorough understanding of their current position, but also ensuring they have a plan to respond in complex and dynamic environments and reduce perceived uncertainty. This research further provides theoretical contribution by filling the literature review gap as a comprehensive list of megatrends and trends that will be identified. Researchers can focus on each of the megatrends and its implications and develop supply chain scenarios. Thus, the results of this chapter will be further used in the next chapters as a basis for future scenarios generation. The remainder of this chapter is organized as follows: Sect. 2 outlines the research design; Sect. 3 presents and discusses the findings of the literature review. Section 4 draws conclusions and discusses future research avenues.

2 Methodology

A systematic literature review and a workshop with experts serves to identify relevant megatrends and trends for supply chain management. According to Denyer and Tranfield (2009), the systematic literature review process entails five steps: (1) process question formulation, (2) locating literature, (3) study selection and evaluation, (4) analysis and synthesis, and finally (5) reporting and using the results. The steps are described below, apart from the first step as it has been already discussed in the previous sub-section and the final step, i.e. reporting and using of the results, which is presented in the next sub-section.

The search of the studies was conducted from November 2017 to January 2018. The following keywords were used to find the relevant studies: (supply chain management) OR (logistics) OR (manufacturing) OR (transportation) OR (process manufacturing) OR (distribution) AND (future supply chain) OR (next generation supply chains) OR (megatrends) OR (trends).

Relevant journal papers and book chapters were identified by using the search field "Topic" to screen well-known academic databases namely ABI/INFORM Global, Academic Search Premier (EBSCO), Science Direct, Emerald and Google Scholar.

Our research was not limited to specific areas e.g. "Engineering", "Operations Research Management Science".

Apart from journal papers and book chapters, grey literature that is not controlled by commercial publishers and entails government, academics, business and industry in print and electronic formats supplements the literature review. The grey literature can minimize bias, "increase reviews' comprehensiveness and timeliness, and foster a balanced picture of available evidence" (Paez 2017, p. 233). Grey literature identified by using web searching, particularly the Google search engine was utilized (file type: pdf search filter, as most of the reports, conference papers etc. are in the form of PDFs) or search within certain websites was also followed e.g. PricewaterhouseCoopers, Roland Berger websites to identify information regarding a specific megatrend or trend e.g. resource scarcity, climate change.

The risk of bias was reduced by implementing clear exclusion and inclusion criteria. As our search shall support developments of the future, we only integrated studies from 2010 onwards. The following filters were used to include the most relevant studies: title, abstract and keywords, introduction, conclusion were checked. Duplicate studies were excluded as well as articles or reports that are irrelevant and not written in English, leading to the review of 125 studies. Multiple databases were used, thus the authors contributed with different relevant articles to minimize bias (Kalaitzi et al. 2018a).

The data was synthesized via thematic analysis using the iterative thematic synthesis process and the NVivo software. 'Open coding' was used to identify trends within the 349 studies and thus create the first-order themes, the trends. According to Collis and Hussey (2009, p. 179) *"The codes are labels which enable the qualitative data to be separated, compiled and organised"*. Then the second-order themes were created, which are the megatrends, by connecting the first-order themes. The last step was to link all the related second-order themes under one aggregate dimension, namely Political, Economic, Social, Technological, Legal and Environmental (PESTLE). By utilizing the PESTLE analysis all the external forces/factors in the macro environment can be captured. Managers in the field of supply chain can use these factors to identify where supply chains currently stand and assess their implications on the future development of their business. A similar approach has been applied in other studies e.g. Yudha and Tjahjono (2019) who analyzed renewable energy industries to identify inefficient legislations and support the development of new strategic policies in the fossil fuel industry. Figure 1 describes the PESTLE dimensions and its content as used by Yudha and Tjahjono (2019).

For example, in the political dimension two second-order themes emerged, namely protectionism (first-order themes: import tariffs, quotas, different tax structures) and political stability (first-order themes: terrorism/conflicts). To identify the first-order themes, the following procedure was applied: the authors initiated a data extraction via randomly selecting a sample of studies to keep the data extraction consistency. The final findings were checked for consistency at a meeting that was arranged to discuss and resolve any disagreements.

After the systematic literature review, a workshop with 18 academics and practitioners from the UK, Germany, Italy, Netherlands, Belgium, Spain and Portugal was held (see Fig. 2). A mind mapping software supported the discussion to refine and extend the findings of the megatrends and trends gained from the literature review. An expert's workshop is a cost-effective and time efficient method in comparison with

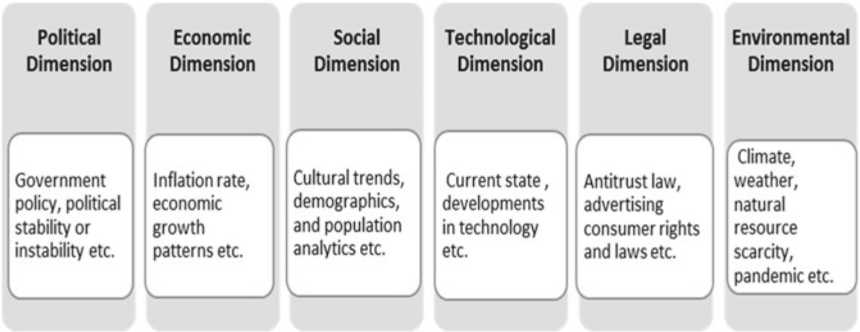

Fig. 1 PESTLE dimensions. Adapted from Yudha and Tjahjono (2019)

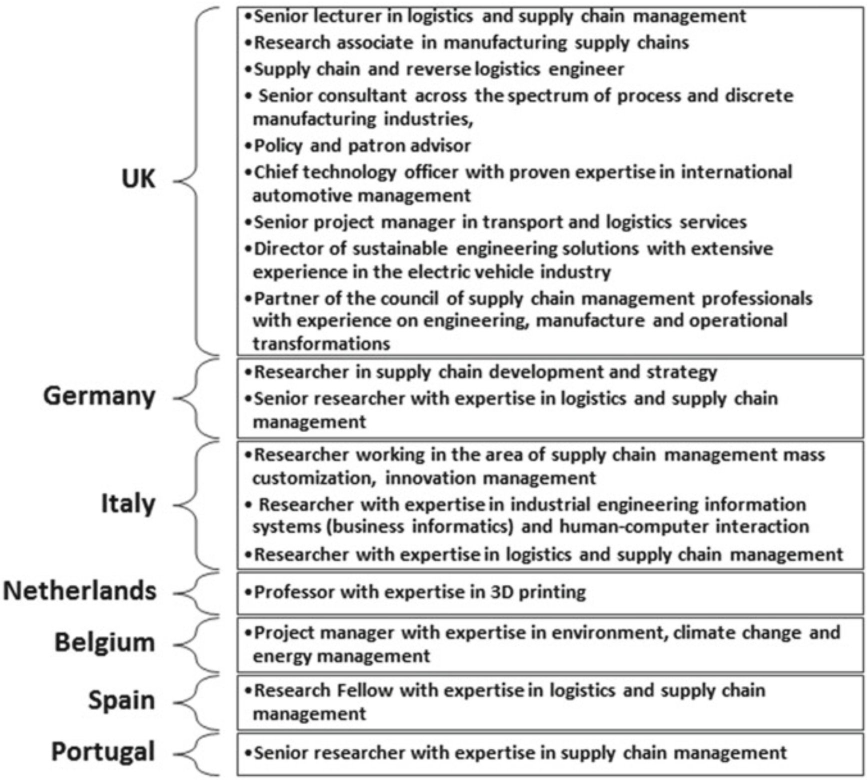

Fig. 2 Workshop participants across seven countries

others such as Delphi research; as the experts gather at the same time and location, it maximizes the compilation of information. It thus leads to richness of information, and enable the experts to participate actively. The workshop participants for the conducted expert workshop are listed in Fig. 2.

3 PESTLE Analysis

Based on the thematic analysis of the secondary and primary data, 23 megatrends and 72 trends emerged which are further explored and presented in the below sub-sections based on the aggregate PESTLE dimensions.

3.1 Political

One of the most important political changes emerging over the last years is protectionism including several trade policies such as tariffs and import quotas, thus policies that try to protect domestic industries against foreign competition. For example, European Union (EU) duty on imports cars from the United States (US) is 10%, whereas the US duty on imports from the EU is only 2.5% (Europa 2015). Another example of protectionism is the US import tariffs of 25% on steel and 10% on aluminum. Companies operating in Mexico and China may be affected by increasing import duties and tariffs (PwC 2017). Regarding quotas, China applied those for rare earth elements from 2005 until 2015 until the World Trade Organization forced China to remove the export quotas. Apart from tariffs and quotas, governments offer subsidies (e.g. cheap loans) to local firms so they can compete well against foreign imports (de Kluyver 2010). For example, the EU offers more than €112 billion per year of fossil fuel subsidies to the transportation industry (Hill 2017). Last but not least, it needs to be highlighted that the total tax share in consumers' prices and taxation systems are not the same across the globe and thus integrate complexity into the supply chain. For instance, different measures to calculate tax are used in Bangladesh, where taxation for tyres is based on retail prices whereas cigarette length is taken into account in India (Shang et al. 2015).

Another megatrend is related to political stability, an indicator of growth, which is crucial for companies. In contrast, political instability (i.e. terrorism/conflicts such as wars, social unrest) can have severe impacts on supply chain operations. For instance, the attack in the twin towers of New York City in September 11, 2001 led Ford, an automotive manufacturer, to shut down five of its plants in the USA and to deficit in land imports exceeding US $350mln (Bueno-Solano and Cedillo-Campos 2014). Regarding social unrest, all regions face some degree of instability, e.g. as anti-government demonstrations, riots, and strikes. For example, "labor issues at West Coast container ports disrupted service in 2015, drove volumes to other ports, and

Table 1 Political dimension megatrends and trends

Megatrends	Trends	References
Protectionism	Import tariffs, quotas, subsidies different tax structures	Benjelloun et al. (2009), Boston Consulting Group (2016), BVL (2013), Clausen et al. (2014), Deloitte (2015a), DHL (2013, 2016a, 2017) Hajkowicz et al. (2016), Deloitte (2015b), Harrington (2015), Kewill (2013), PwC (2009), Schuckmann et al. (2012), SMMT (2015), von der Gracht and Darkow (2011)
Political stability	Terrorism/conflict, social unrest	BVL (2013), Cerasis (2017), DHL (2012), FTA (2016, 2017), Grant Thornton (2017), PwC (2011, 2017), Sana (2017), von der Gracht and Darkow (2011), World Bank Group (2017)
Supranationalism	Trade agreements, free movement	KPMG (2014, 2017), WEFORUM (2016), World Economic Forum (2016)

altered seasonal patterns" (Kearney AT 2016a, p. 18). Finally, the megatrend supranationalism is linked with trade agreements and free movement which determine supply chain decisions (e.g. the number and location of the production facilities, supplier selection). Brexit provides an example for this megatrend with a direct impact on supply chains. Specifically, as trade agreements will be restricted some studies highlight that 32% of EU suppliers will be substituted by local suppliers and 46% of EU companies will avoid UK suppliers (McKevitt 2017). Table 1, provides an overview of the megatrends and trends related to the political dimension.

3.2 Economic

A key trend that emerged under the economic dimension is economic growth in countries such as China and the MINT (Mexico, Indonesia, Nigeria, and Turkey) results in global trade shift (Francesco and Ardita 2015). It is projected that by 2030, China will be the largest economy in terms of Gross Domestic Product (GDP) while by 2050 India would be the third largest economy in the world. This will influence the demand, and the design of the supply chain networks (PwC 2015). Glocalization is another trend that entails the process of adapting international products to the local culture in which they are sold and also impact supply chain configuration and product structure (Hong and Song 2010). For example, fast-food chains such as McDonald offer their global, iconic brands but at the same time there are local menu options.

Moreover, digital economy trend appeared through the literature where customers use online platforms (e.g. Airbnb, Uber) to facilitate the process of sharing. Sharing economy industry meanwhile established a worth of £7 billion a year (Kleiner Perkins 2017). Peer-to-peer transportation facilitated transactions of €5 billion in 2015 (PwC 2016a) and it can be applied to inter/ intra- city logistics and movement of goods by ride-sharing or by truck-sharing (DHL 2016a). Regarding the trend from an economy of goods to an economy of services, new selling platform or new, upcoming internet services will be introduced. For example, grocery stores with both virtual and physical presence are introduced by platform providers e.g. by Amazon and Alibaba. Concerning the megatrend financial innovation, there are trends such as cashless payments and digital currencies that aim to improve the security of the financial transactions in the supply chains. Thus, business-to-consumer (B2C) transactions are increasingly digitized (Bons et al. 2012). Last but not least, financial technology (Fintech) firms are expected to revolutionize supply-chain finance. However, FinTech companies face regulatory uncertainty that can act as burden on companies' prospects for growth (Boston Consulting Group 2017).

Thus, under the economic dimension three megatrends and 11 trends emerged (see Table 2).

Table 2 Economic dimension megatrends and trends

Megatrends	Trends	References
Global trade shift	Economic growth in emerging economies, export growth, investment, globalization, glocalization and emergence of born-global firms	Accenture (2016), Aggelakakis et al. (2015), ALICE (2013), BVL (2013), Kearney AT (2014, 2016a), Boumphrey and Brehmer (2017), Cerasis (2017), Clausen et al. (2014), Csiro (2014, 2016), Deloitte (2017), DHL (2015, 2016a, 2017), Elmegaard (2016), European Agency for Safety and Health at Work (2016), FTA (2016), Gernandt (2012), Hajkowicz et al. (2016), Harrington (2015), ITC (2017), McKinsey Global Institute (2012, 2016a, 2016b), PwC (2015, 2016b, 2011), Roland Berger (2014), Sana (2017), Schuckmann et al. (2012), SMMT (2015), UNIDO (2013), UKCES (2014), United Nations (2010), von der Gracht and Darkow (2011), World Bank Group (2017)
Digital economy	Sharing economy, from an economy of goods to an economy of services	Boumphrey and Brehmer (2017), Grant Thornton (2017)
Financial Innovation	Digital currencies, cashless payment, the financial technologies (Fintech) revolution	Capgemini (2017), EY (2017)

3.3 Social

Under the social dimension a key megatrend that identified is population growth. World population is forecasted to reach 8.5 billion by 2030 and the main contributors to this growth will be Africa and Asia followed by Northern America, Latin America and the Caribbean and Oceania (United Nations 2015). Consequently, demand for land and food will grow substantially by 2050. Another trend considers the ageing population as it projected that 56% of the total population will be 60 years or over by 2030, mainly in the developed regions (United Nations 2015). This will have an impact on the logistics industry as e.g. the average age of truck drivers has increased more rapidly in comparison with other industries due to the inability of attracting young workers entering the industry (The Conference Board of Canada, 2013). There is a shortage of 59,000 Heavy Goods Vehicle (HGV) drivers in the UK (FTA 2019). Apart from drivers, hiring skilled workers is a big challenge for supply chain managers as there is a shortage of workers with the right skills that delay also the implementation of digital technologies (MHI 2020). However, it is suggested that 35 million people will move from less developed countries to developed ones between 2015 and 2030 (Roland Berger 2017) that will lead to workforce expansion and therefore increasing demand and investment. New megacities and smart cities particularly will grow, and the related needed investments estimated to $1.8 trillion by 2030 (OECD 2015). By 2025 it is expected that more than 60% of the world population will be in urban cities (United Nations 2014).

These trends will lead companies to look for alternative transport modes that suit the urban centers and force them to change their overall distribution strategies with the ultimate goal to respond quickly to a rapidly changing and highly sophisticated consumer landscape (Öberg and Graham 2016). For example, the increasing demand for urban logistics led logistics providers to collaborate with retailers, which is called "re-logistification". Another phenomenon is logistics sprawl i.e. relocation and concentration of logistics facilities towards suburban areas. Multi-floor logistics facilities (i.e. "flexible distribution centers whereby a fleet of mobile warehouses are parked at strategic locations throughout the city" will be utilized (CBRE 2017). Last but not least, there is a trend towards underground cargo transporters (DHL 2012).

In addition, consumption pattern will change due to various trends such as middle-class explosion and on-line shopping that will lead to the growth in the parcel market and in the last-mile delivery and reverse logistics services. These trends already led retailers to insource portions of their logistics function and build their own networks e.g. Amazon (PwC 2011). The recent pandemic also led consumers to panic buying and stockpiling; thus, supply chain managers faced the challenge with regards to demand and stockouts (Hall 2020). Due to the quarantine measures of the coronavirus crisis, several retailers such as Hennes & Mauritz AB, The Body Shop temporarily closed their physical stores which led online sales to increase. For example, online sales increased 49% between March 12-April 11 2020 in the USA; grocery (e.g. Instacart) and electric/electronics retailers are the most important online players while there only a few apparel companies that have been doing well e.g. Lululemon (Popper

2020). Thus, most of the customers are buing only essential items and according to Foolproof survey, 72% of adults in the UK supported that had either worn gloves or cleaned a public touch surface and 48% used contactless payment; thus, this pandemic will change the way that transactions are made and companies should adapt and use mobile payments, QR codes and completely touchless payments (Rigby 2020).

The new business models need to take into consideration the increasing social media engagement e.g. 68% of millennials tend to buy specific products or services based on friends' social media (Nielsen 2016). Individualization has an impact on the production structures to be more decentralized e.g. healthy lifestyle led to demand for fresh, healthy, unprocessed foods with short shelf life (Mat et al. 2015). Technologies such as 3D printing will enable customers to get involved into the design phase as the customization of the products and services is an added value (Kudus et al. 2016). In the logistics sector, dedicated fleets are used to ensure service requirements are met. In Table 3 seven megatrends and 20 trends identified under the social dimension.

3.4 Technological

Under the technological dimension digital transformation has emerged as a key megatrend. Technological advances have increased industrial productivity and there is a rise of new digital industrial technology known as Industry 4.0 which is powered by several technological advances such as big data analytics and robots (Hydrogen Council 2017). It is projected that big data and analytics software sales will grow to $70 billion by 2020 and they will be utilized in several industries (IDC 2017). For instance, companies in the pharmaceutical industry can utilize predictive analytics to detect demand spikes, stocks and delivery resources ahead of time (DHL 2017). Within the logistics industry, this trend can be applied for route optimization and real-time tracking of resources (CBRE 2017). Based on the survey from the Business Continuity Institute, most of the companies (59.6%) utilize big data analytics for their supply chain management to remove silos and enable them to have access to more comprehensive set of data (Business Continuity Institute 2019).

The digital transformation forces companies to rethink what customers value most and adjust operating models to achieve competitive advantages. For example, it is expected that 36% of financial services firms will make substantial investments in blockchain in the next three years (Harvey 2017). Blockchain can be used in supply chains to avoid paperwork processing in ocean freight, identification of counterfeit products, minimizing the inefficiencies in last-mile deliveries, and tracking of origin (Hackius Petersen 2017; PWC 2019). Regarding the megatrend technology development and automatization, the use of robots in factories and cyber physical systems will affect manufacturing companies in terms of production systems (Leitao et al. 2015). Developments within robotics enable 'reshoring' activities: reintroducing domestic manufacturing to a country. For example, Adidas sportswear manufacturer uses "intelligent robotic technology" and brought parts of their shoe production back to Germany from China.

Table 3 Social dimension megatrends and trends

Megatrends	Trends	References
Population growth	Population boom in the developing countries, growing demand of resources (e.g. land)	Accenture (2016), Aggelakakis et al. (2015), Boumphrey and Brehmer (2017), Clausen et al. (2014), DHL (2013, 2016a), Harrington (2015), Kwiatkowski and Schäfer (2017), McKinsey Global Institute (2011), PwC (2012, 2016b), Roland Berger (2017), United Nations (2010), UN (2015), van Buren et al. (2016), Veolia (2016), WEF (2013)
Demographic change	Ageing population boom in developing countries, young population boom in developing countries, migration flows, labor shortages	Accenture (2016), ALICE (2013), Kearney AT (2016b), Boston Consulting Group (2016), Cranfield University (2017), Csiro (2016), BVL (2013), Deloitte (2017), DHL (2016b), European Agency for Safety and Health at Work (2016), Frost and Sullivan (2017), FTA (2016, 2017), Grant Thornton (2017), Kewill (2013), KPMG (2016), McKinsey Global Institute (2011, 2012), Miebach (2017), PwC (2012, 2015, 2016a), Roland Berger (2014), Sana (2017), SCM World (2014), SEMLEP Logistics (2013), Sikich (2017), SMMT (2015), Veolia (2016), von der Gracht and Darkow (2011), Wisskirchen et al. (2017), World Bank Group (2017)
Urbanization	Megacities, smart cities	Accenture (2016), Aggelakakis et al. (2015), Barclays (2014), Benjelloun et al. (2009), Bielefeldt et al. (2013), Boumphrey and Brehmer (2017), CBRE (2016, 2017), Citylab (2017), Clausen et al. (2014), Csiro (2014), Deloitte (2017), DHL (2012, 2013, 2016a, 2017), Elmegaard (2016), European Agency for Safety and Health at Work (2016), Gernandt (2012), Grant Thornton (2017), Harrington (2015), Invata (2017), ITC (2017), KPMG (2016), Mehmood et al. (2016), PwC (2009), Schuckmann et al. (2012), UN (2015), UNIDO (2013, 2016), United Nations (2010), Veolia (2016), von der Gracht and Darkow (2016), PLA (2016), PwC (2015, 2016b), Roland Berger (2017), World Bank Group (2017), WEF (2013, 2016)

(continued)

Table 3 (continued)

Megatrends	Trends	References
Change in consumption pattern	Middle-class explosion, healthy diets and lifestyles, consumerism	Kearney AT (2014, 2016a), Barclays (2014), BVL (2013), Cerasis (2017), Csiro (2014), Deloitte (2015a, 2017), DHL (2013, 2017), Gernandt (2012), Horenberg (2016), Kewill (2013), Lee et al. (2016), PwC (2016c), Schmidt (2013), van Buren et al. (2016)
Individualism	New customer relationship, new shopping experience, increased customization	Kearney AT (2016b), Barclays (2014), Boumphrey and Brehmer (2017), BVL (2013), CBRE (2016), Cerasis (2017), Clausen et al. (2014), Csiro (2014, 2016), Deloitte (2015a, 2017), DHL (2012, 2013, 2016a), European Commission (2010), EY (2014, 2016), Gernandt (2012), Infor (2016), Invata (2017), KPMG (2016), Kwiatkowski and Schäfer (2017), McKinsey Global Institute (2012), PwC (2009, 2011, 2015, 2016a, 2017), Sana (2017), UNIDO (2016), Veolia (2016), WEF (2016), World Bank Group (2017)
Digital natives	Change of communication patterns, change of purchasing patterns, reshaping the workplace	PwC (2016b)
Knowledge based economy	Increasing demand for high-qualification jobs, emerging skills required, continuous learning culture	Business Europe (2011), Deloitte (2017), OECD (2015)

Apart from robots, additive manufacturing enables easier prototyping and product development and move manufacturing activities closer to the final customers. This technology will reform logistics facilities and the relationships with the suppliers who provide the materials (Chen 2016). It is expected that 3D printing will reach a global value between $180 billion and $490 billion by 2025 (DHL 2016a). 3D printing will rise competition with e.g. small businesses that are funded through crowdsourcing (Mohr and Khan 2015). This technology will also impact the warehousing industry as along with the servitization some products can be stored digitally thus minimizing the inventory in the warehouses (Horenberg 2016). Regarding distribution, there will be a reduction in shipping, but it is important to highlight that raw materials are still needed (Chen 2016).

Distribution will be also impacted by drones that are expected to be used for quick delivery, thus minimizing the traffic on the roads, internal delivery and for tracking inventory (DHL 2014). Drones can play an important role in intralogistics, e.g. intraplant transport, but there are still issues such as regulations and public concern regarding the unmanned aerial vehicle (DHL 2014). Another important element is the autonomous vessels that can detect and adapt to changing sea and weather conditions and avoid collisions (KPMG 2015). There will be only three or four major liner companies, operating either as digitally enabled independents or as small units. Loading, stowage, and sailing will be fully autonomous to unloading directly onto autonomous trains and trucks and drones (McKinsey and Company 2017).

Transport electrification is another megatrend that is influenced by regulations regarding emissions and fuel efficiency. The main impacts on supply chain and logistics industries will be the use of battery electric vehicles, hydrogen fuel cell electric vehicles and hybrid vehicles. It is expected that 1 in 12 cars sold in Japan, California, South Korea and Germany would be powered by hydrogen by 2030 (Hydrogen Council 2017). Recently the UK government has announced £37 m of investment in developing electric cars, ships, and planes in the UK (UKRI 2020). There is not much availability and choice of electrified transport logistic vehicles in the logistics industry, but new materials lead to reduction in the weight of vehicles thus minimize fuel or electricity consumption (Kleiner et al. 2017). Last, renewable energy sources as a megatrend has several impacts on supply chain and logistics industries e.g. companies such as Apple aim to procure 100% of their electricity from renewable sources to minimize emissions from supply chain operations) (Apple 2018).

Thus, in Table 4 the four megatrends and 18 trends are presented.

3.5 Legal

Consumer protection laws are getting stronger so that consumers can easily return products free of charge or under warranty (Deloitte 2013) and companies have to recall products in case of problems towards customer's safety. These trends impact the return process of supply chain. For instance, Toyota recalled 5.8 million vehicles because of faulty airbags. In addition, there are new EU privacy regulations that aim to protect any personal information. There are different directives regarding consumer protection in the digital market i.e. Directive 2011/83/EU on consumer rights, Directive 95/46/EC on the protection of individuals with regard to the processing and free movement of personal data.

Intellectual property law tries to secure the rights to inventions. However, for companies operating in certain countries such as China, it is challenging and there is a fear of security risks and loss of control when exchanging data (PwC 2016b). New emerging technology such as 3D printing can lead to several issues regarding the intellectual property, too; companies and governments need to solve any legal issue to enable technologies to contribute a large scale of open innovation (Chen 2016).

Thus, data exchange e.g. data regarding inventory, production processes, maintenance and the supply status of products or even financial data is a "big topic" and data sovereignty concepts need to be established for the protection of intellectual property. Data sovereignty is guaranteed by the following three aspects: (1) Data remain decentral and are not integrated in a joint data pool, (2) A precisely graded

Table 4 Technological dimension megatrends and trends

Megatrends	Trends	References
Digital transformation	Big data analytics, artificial intelligence, cloud-based computer systems, blockchain, Internet of Things	Gernandt (2012), BVL (2013), Clausen et al. (2014), Hajkowicz et al. (2016), DHL (2016b, 2017), Harrington (2015), PwC (2009), Schuckmann et al. (2012), von der Gracht and Darkow (2011), Cerasis (2017), DHL (2012, 2016a), FTA (2017), Grant Thornton (2017), PwC (2011, 2016a, 2017), Sana (2017), Kearney AT (2016a), Boumphrey and Brehmer (2017), Csiro (2014, 2016), Deloitte (2017), McKinsey Global Institute (2012, 2016a, 2016b), UKCES (2014), DHL (2015, 2017), Elmegaard (2016), European Agency for Safety and Health at Work (2016), WEF (2016), Kwiatkowski and Schäfer (2017), UN (2015), Veolia (2016), WEF (2013), Deloitte (2017), KPMG (2016), Miebach (2017), SCM World (2014), Sikich (2017), Wisskirchen et al. (2017), Barclays (2014), Bielefeldt et al. (2013), CBRE (2017), Mehmood et al. (2016), PLA (2016), UNIDO (2016), Lee (2016), von der Gracht and Darkow (2016), PwC (2016a), Schmidt (2013), Horenberg (2016), European Commission (2010), Infor (2016), PwC (2017), Boston Consulting Group (2015), Capgemini (2011), Deloitte (2013, 2016), EFT (2016), Heijster and Huijbers (2012), Jablonski (2016), PwC (2016a), Roland Berger (2017), Technopolis and Fraunhofer (2016), WEF (2017), Digital map (2017)
Technology development and automatization	Robots, cyber-physical system, augmented reality and virtual reality, 3D printing/additive manufacturing, drones, autonomous systems, automated guided vehicles, wearable devices	
Electrification of transport	Battery electric vehicles, hydrogen fuel cell electric vehicles, hybrid vehicles	FCH (2015), Hydrogen Council (2017), Markets and Markets (2015), Schorsch (2017), McKinsey (2010), Kleiner et al. (2017), Speranza (2018), Theverge (2016), S2R (2017)
Renewable energy sources	Production and storage of clean energy and application to transportation and industry, renewable energy for industrial processes	Hydrogen Council (2017), IGI Global (2017)

certification concept and (3) Security of infrastructure through new technological solutions (PwC 2016a). Last but not least, social and environmental regulations aim to achieve sustainable development through its activities on the environment as well as on employees and consumers (Tai and Chuang 2014).

Over the last decade, corporate social responsibility disclosure has increased dramatically. Moreover, vehicle electrification market is driven by stringent emission and fuel efficiency regulations. EU legislation set mandatory emission reduction

Table 5 Legal dimension megatrends and trends

Megatrends	Trends	References
Consumer protection laws	Cross-border payments, return products free of charge or under warranty, product safety regulations, privacy	Deloitte (2013), Durovic (2019)
Intellectual property law	Patents, data sovereignty	EvaluatePharma (2012)
Social and environmental regulations	Corporate social responsibility, emissions control regulations, waste and resources management regulations	Accenture (2016), Aggelakakis et al. (2015), Kearney AT (2016b), Citylab (2017), Deloitte (2013), DHL (2016a, 2012), ITC (2017), Heijster and Huijbers (2012), Kewill (2013), PwC (2011, 2015), van Buren et al. (2016), Veolia (2016), von der Gracht and Darkow (2011)

targets for new cars sold in the EU specifically the fleet average should be 95 grams per kilometer by end of 2020 (Europa 2018). In addition to this, there is a target to reduce the greenhouse gas intensity of fuels by 6% by 2020 and maritime transport emissions levels at least 40% by 2030 (IMO 2018). The EU is setting the rules in order to boost resource efficiency and promote recycling e.g. EU's Raw Materials Initiative. These regulations could lead to the relocation of carbon intensive companies and specific industries to regions with not so strict regulations (Ceniga and Sukalovaba 2015). The European Commission recently set a new circular economy action plan. More specifically there is a revision of EU waste legislation that includes new targets and processes to minimize packaging waste (e.g. harmonize separate collection systems), and "mandatory essential requirements" for packaging (i.e. reusable or recyclable) placed on the market (European Commission 2020). The review aims at restricting waste exports that could have harmful impacts in third countries.

Under the legal dimension three megatrends and nine trends emerged (see Table 5).

3.6 Environmental

Pollution is a main trend when it comes to climate change. Air pollution, water pollution, and land pollution count to the major types of pollution. Focal firms are responsible for up to 80% of overall supply chain emissions so they are developing integrated approaches and strategies to minimize carbon emissions (Zimon et al. 2019). For example, Walmart, an American retailer, has launched a program to achieve a reduction of CO_2 emissions from its Chinese suppliers by 50 million tons by 2030 (Reuters 2018). Furthermore, accidents, cancelation and delays due to atmospheric changes that are related with the increasing CO_2 levels can lead to supply chain network disruptions. As pollution leads to increasing temperatures it will impact the transportation and logistics industries due to e.g. asphalt deterioration, buckling of rail lines and damage of the expansion joints on bridges and highways (Schwartz et al. 2014). Packaging will also be in the spotlight over the next five years as fast-tracked deliveries and frequent single-item shipments, create more carbon emissions and packaging waste (DHL 2019).

The depletion of resources such as water, oil (i.e. energy scarcity), and rare earth elements have been highlighted in many studies e.g. Bell et al. (2012). Resource scarcity, the second megatrend, is influenced by the global population, and the increasing demand for resources from consumers, regulations and geopolitical risks (Balatsky et al. 2015; Kalaitzi et al. 2018b). As population grows and the living conditions in developing countries rises along with changing eating habits, more people will require food or develop particular eating habits e.g. more meat, which in turn requires more water and agricultural area.

Specifically, global freshwater withdrawal by the manufacturing industry will grow more than 5% by 2050, over a year 2000 baseline, from 245 to 1552 billion m^3 (Sachidananda et al. 2016). Companies, particularly the ones for whom water is the primary ingredient in their products, will face disruptions in their operations, e.g. Coca-Cola had to shut down factories in India due to social forces supporting Coca-Cola exploited water resources that were scarce in these regions.

Moreover, land scarcity is a big issue in densely populated cities, and logistics industry solutions have been trying to maximize land productivity e.g. innovative logistics hub construction. For example, a logistic hub will be completed in Singapore in 2019 integrating a multi-level inland container depot, a heavy vehicle park and warehouses (Mizar 2016). Apart from water and land, the energy demand worldwide is forecasted to increase; industrial energy demand will raise by 50% from 2015 to 2040 and the energy demand for the ships, planes and trains that carry products to factories and to markets will increase by 65% in the same timeline. Last but not least, rare earth elements scarcity is a crucial issue in manufacturing supply chains. Those elements are used in high technology-based products for different sectors, inter alia defense. China has 35% of global supply of the rare earth elements (Zhou et al. 2017) and applies tax and export quotas impacting the availability, supply and prices of those resources (Humphries 2003).

Another megatrend that emerged under the environmental dimension is catastrophic events/hazards e.g. flood, drought and pandemic. In particular there are three trends: natural disasters (like hurricanes, volcano eruptions), biological risks (like pandemic) and man-made disasters. Natural disasters can disrupt the supply chains causing interruption in trasportation and production processes: in Europe, recorded losses from climate extremes cost on average EUR 11.6 billion per year between 1980 and 2013 (European Environmental Agency 2017) and damages are projected to increase reaching 32 billion€ per year by 2050 (COACCH project 2018[1]). For example, after the earthbreak in Japan on 2011, the most important car manufacturers froze their production losing US$72 million a day (Arto et al. 2015); in particular, for

[1] https://www.ecologic.eu/sites/files/publication/2018/2811-coacch-review-synthesis-updated-june-2018.pdf.

several weeks, a shortage of over 150 parts left Toyota's North American operations operating at 30% of capacity (Canis 2011). Regarding biological risks, it is possible to mention for example the spread of pandemic, supply chains should be mapped and restructured after the outbreak of SARS in 2003 but most of the companies thought that such a disruption is not likely to occur soon again and they were not willing to spend a large amount of labour and time required for these activities (Choi et al. 2020; Simpson 2020). Covid-19 outbreak in 2020 showed the importance of being proactive as this pandemic shut down temporarily factories (e.g. companies from the automotive and apparel industry), and led to traffic/ transportation restriction enforced by quarantine policy. Moreover, some countries enforced a ban to a few product categories e.g. Indonesia and Jordan banned imports of live animals from China and other countries saving vital medical equipment e.g. ventilators, face masks for their own citizens. It is forecasted that Covid-19 outbreak will cost the global economy at least $1trn (Simspon 2020). The last trend is related to disasters caused by human behavior; man-made disasters impact on supplier flow, warehousing, distribution and transportation. Ericsson in Spring 2001 lost $400 million just because of a fire in a supplier's plant: the gaps of radio-frequency chips were supplied only by that supplier; it took pretty long for Ericsson to get aware of the situation and as a consequence the company had to give up its mobile phone business section (Munim et al. 2015). As consequence of an Explosion at BASF plant in Ludwigshafen in 2016, 15% of raw materials were missing for the entire supply chain and the production of some products at BASF has been stopped for many weeks (Ivanov 2018).

Under the environmental dimension three megatrends and six trends emerged (see Table 6).

4 Conclusion

Megatrends are reshaping society, economies, politics and the environment; so, they can be used to forecast future supply chain developments. There are only a few academic papers and reports that focus on specific megatrends in the field of supply chain management (i.e. Bowersox et al. 2000; Gernandt 2012; Jiang et al. 2017; Mat et al. 2015; Schuckmann et al. 2012; Seppälä 2016; Schmidt 2013; Stank et al. 2015; Sweeney 2013; von der Gracht and Darkow 2011, 2016) and do not provide a comprehensive view on trends and megatrends. This research addresses that gap through an extensive systematic review of the literature. The main contribution of this research is the comprehensive review and assessment of megatrends which was based not only on scientific publications, but also on sectoral studies, and governmental reports while, in addition, further insights have been collected and merged on the megatrends/trends within an interactive session. The need to expand the review and include a variety of publications (e.g. reports by consulting companies) was identified as a research opportunity in the literature review conducted by Malik and Janowska 2018. Based on a systematic literature review and a workshop, a total of 23 megatrends (M) and 72 related trends (T) were identified as the summary in Table 7

Table 6 Environmental dimension megatrends and trends

Megatrends	Trends	References
Climate change	Pollution	Bielefeldt et al. (2013), Clausen et al. (2014), DHL (2013, 2012), FTA (2016), European Environmental Agency (2012), Accenture (2016), ITC (2017), PwC (2015), Mehmood et al. (2016), PLA (2016), Planning Institute Australia (2016), PwC (2009), Roland Berger (2016), Schwartz et al. (2014), United Nations (2015, 2010), UNIDO (2013), WEF (2013)
Resource scarcity	Lack of resources such as water, land, energy, food and rare earth elements, waste increase	Accenture (2016), Aggelakakis et al. (2015), ALICE (2013), Kearney AT (2014, 2016a), Barclays (2014), Boumphrey and Brehmer (2017), CBRE (2016), Cerasis (2017), Clausen et al. (2014), Csiro (2014), Csiro (2016), Deloitte (2013), DHL (2012, 2015, 2016a), European Commission (2010), Harrington (2015), Frost and Sullivan (2017), FTA (2016), Industry Innovation council (2011), Invata (2017), Kewill (2013), KPMG (2016), PLA (2016), Planning Institute Australia (2016), PwC (2009, 2011, 2015, 2016b), Roland Berger (2016), Schuckmann et al. (2012), United Nations (2010), van Buren et al. (2016), Veolia (2016), von der Gracht and Darkow (2011, 2016), WEF (2013, 2016)
Catastrophic events/hazards	Natural disaster, biological risks (e.g. pandemic),man-made disasters	Doherty and Botwright (2020), FTA (2020), Rogers and Oak (2020), Simpson (2020)

shows. To our knowledge this is the first published comprehensive literature review on megatrends and trends in the field of supply chain management.

The identified megatrends (e.g. globalization) could help managers and researchers alike to consider impacts on product, process and supply chain configuration. In particular, the study provides to managers in a systematic way megatrends and trends that are critical for the generation of future industrial scenarios and could offer a starting point to customise specific long-term strategies for their company.

Table 7 Overall megatrends and trends identified

Dimensions	Megatrends	Trends
Political	Protectionism	Import tariffs
		Quotas
		Different tax structures
		Subsidies
	Political stability	Terrorism/conflict
		Social unrest
	Supranationalism	Trade agreements
		Free movement
Economic	Global trade shift	Economic growth in emerging economies
		Export growth
		Investment
		Globalization
		Glocalization
		Emergence of born-global firms
	Digital economy	Sharing economy
		From an economy of goods to an economy of services
	Financial innovation	Digital currencies
		Cashless payment
		The financial technologies (Fintech) revolution
Social	Population growth	Population boom in the developing countries
		Growing demand of resources (e.g. land)
	Demographic change	Ageing population boom in developing countries
		Young population boom in developing countries
		Migration flows
		Labor shortages
	Urbanization	Megacities
		Smart cities
	Change in consumption pattern	Middle-class explosion
		Healthy diets and lifestyles
		Consumerism
	Individualism	New customer relationship
		New shopping experience

(continued)

Table 7 (continued)

Dimensions	Megatrends	Trends
		Increase customization
	Digital natives	Change of communication patterns
		Change of purchasing patterns
		Reshaping the workplace
	Knowledge based economy	Increase demand for high-qualification jobs
		Emerging skills required
		Continuous learning culture
Technological	Digital transformation	Big data analytics
		Artificial intelligence
		Cloud based computer systems
		Blockchain
		Internet of Things
	Technology development and automatization	Robots
		Cyber-physical system
		Augmented reality and virtual reality
		3D printing/additive manufacturing
		Drones
		Autonomous systems
		Automated guided vehicles
		Wearable devices
	Electrification of transport	Battery electric vehicles
		Hydrogen fuel cell electric vehicles
		Hybrid vehicles
	Renewable energy sources	Production and storage of clean energy and application to transportation and industry
		Renewable energy for industrial processes
Legal	Consumer protection laws	Cross-border payments
		Return products free of charge or under warranty
		Product safety regulations
		Privacy
	Intellectual property law	Patents
		Data sovereignty
	Social and environmental regulations	Corporate social responsibility
		Emissions control regulations

(continued)

Table 7 (continued)

Dimensions	Megatrends	Trends
		Waste and resources management regulations
Environmental	Climate change	Pollution
	Resource scarcity	Lack of resources such as water, land, energy, food and rare earth elements
		Waste increase
	Catastrophic events/hazards	Natural disaster
		Biological risks (e.g. pandemic
		Man-made disasters

This chapter gives a glimpse into the opportunities and challenges that supply chain managers may face in the future; thus, they can develop an early warning system and develop as well as contingency plans. It provides an opportunity to prepare and respond to a broad range of potential disruptions in the future and to create more resilient and interactive supply chains. Based on these results, it is possible to formulate scenarios that describe the evolution and the implications of the identified megatrends and trends on supply chains for the next decade. Although the paper highlights some of the interesting insights in the SCL literature, there are a few limitations of the paper. Future research can consider other megatrends/trends given the dynamic, complex and fast evolving nature of modern supply chains.

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A Methodology for Future Scenario Planning

Saskia Sardesai, Markus Stute, and Josef Kamphues

Abstract The future is influenced by various possible developments and is hence difficult to predict. Still, each company or institution bases its vision and strategic progress on certain assumptions for the future. In order to prepare for various developments of the future, it is reasonable to consider different possible scenarios while building a future vision. Thus, this chapter focuses on the methodological approach for the generation of future scenarios showing what the surroundings for supply chains might be like in a time horizon until 2030. This integrates various political, economic, social, technological, legal and environmental influences and changes. The methodological framework required for generating scenarios is set by a combination of quantitative and qualitative scenario planning methodologies. Close coordination and collaboration between production and logistics guides the underlying scenario design to focus the context on supply chains. While considering trends described in Kalaitzi et al. 2020, this approach results in a set of macro scenarios, each describing a possible future development until 2030. The macro scenarios range from scenarios with progressive developments to regressing or stagnating evolutions.

Keywords Scenario planning · Trends · Supply chain management · Prediction

1 Introduction to Scenario Planning

Scenario planning is a proven approach to coping with uncertainties in today's rapidly changing world (DHL 2012). Since the 1950's, scenario planning has been used to help make public policy decisions—beginning with war game analyses at the Rand Corporation (Wilkinson and Eidinow 2008). Interest in the method has grown at the intersections of academia, the public and private sectors and policymaking.

Scenario planning forms a basis for learning through strategic conversation and it helps to build a consensus in terms of considering the probability of certain future

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developments (so called ‘projections’) (Wilkinson and Eidinow 2008). The methodology supports the creation of different scenarios in order to be prepared for various possible future developments. It results in a set of several scenarios in which each set claims a different probability level. Compared to the fixed results achieved by traditional methods, this methodology provides a set of possible ways forward while retaining uncertainty (Wilkinson and Eidinow 2008). Accordingly, it differs from other future research approaches, such as predictions and forecasts, as it integrates different combinations of future states, so called scenarios.

The methodology is specifically useful in the context of future statements with different levels of uncertainty. It provides a holistic and schematic overview to describe a possible future condition. Each resulting scenario details causal relationships between a set of projections of future developments. It describes a version of the future which originates from the current state of developments (Meinert 2014). The generated scenarios help organisations to react to changes, make decisions, be prepared for and adapt quickly to upcoming environmental changes and thus improve the quality of strategic thinking (DHL 2012). The methodology also allows public authorities to evaluate future developments e.g. to prepare for stocks of mouth and nose masks in case of pandemic events. Thus, the methodology helps organisations and public authorities to prepare for possibilities and to ensure innovative and flexible development (Amer et al. 2013).

Boerjeson et al. distinguish between three main scenario categories, namely predictive, explorative and normative. Predictive scenarios respond to the question “*What will happen?”*; explorative scenarios consider the question *“What can happen?”*; and the normative scenarios focus on “*How can a specific goal be achieved?”*. In addition, they can be classified according to the topic (i.e. global scenarios or problem specific) and its level of aggregation (e.g. macro or micro) (Amer et al. 2013).

The literature for the development of scenarios is diverse and wide-ranging and there are many definitions, typologies and methodologies (Enserink et al. 2013) with different utilities, strengths and weaknesses (Amer et al. 2013). In the underlying topic, the scenarios are intended to serve as an aid to policy planning within the logistics sector. In this case, the explorative long-term horizon within the definition of Boerjeson et al. is considered, aiming at the question: *“What can happen?”*. According to Boerjeson et al. this category is further differentiated into external and strategic scenarios. While strategic scenarios focus on internal factors, external scenarios address the development of external factors that cannot be influenced by an actor, e.g. a company or a political unit (Boerjeson et al. 2006).

2 Methodological Approach for Scenario Planning

With regard to the generation of scenarios, the approach used in this work is closely linked to a methodology proposed by Gausemeier and Plass (2014). The approach belongs to the category of quantitative approaches and uses a cross-impact and consistency matrix to develop a set of scenarios. Being in line with the rational, objectivist school, a cross-impact analysis of future projections serves to identify correlations and causal impacts (Amer et al. 2013). It is complemented by qualitative methods to enhance the plausibility of the scenarios. The resulting scenarios represent macro-scenarios outlining the future industrial surroundings based on a trend analysis according to PESTLE dimensions (**p**olitical, **e**conomic, **s**ocial, **t**echnological, **l**egal and **e**nvironmental influences). The methodology applied here has the strong advantage of allowing several ways for the development of the future and of enabling the inclusion of complex future developments that result from different trends and perspectives. While integrating the complex surroundings, the methodology uses a powerful methodology to compress various future projections to select a few scenarios for a more detailed analysis (Gausemeier et al. 1995). The approach is separated into five different steps as shown in Fig. 1, where the approach as suggested by Gausemeier is compared to the applied approach.

The first step of the Gausemeier approach comprises a definition of the envisaged scope and timeline as well as the underlying decision-field-analysis. Step 2 conducts a scenario-field-analysis that identifies and describes major influencing trends within the decision-field. Step 3 clusters the trends to state future projections. Those projections are integrated into a cross-impact matrix to form future projection bundles and thus preliminary scenarios. Step 4 evaluates the consistency of the

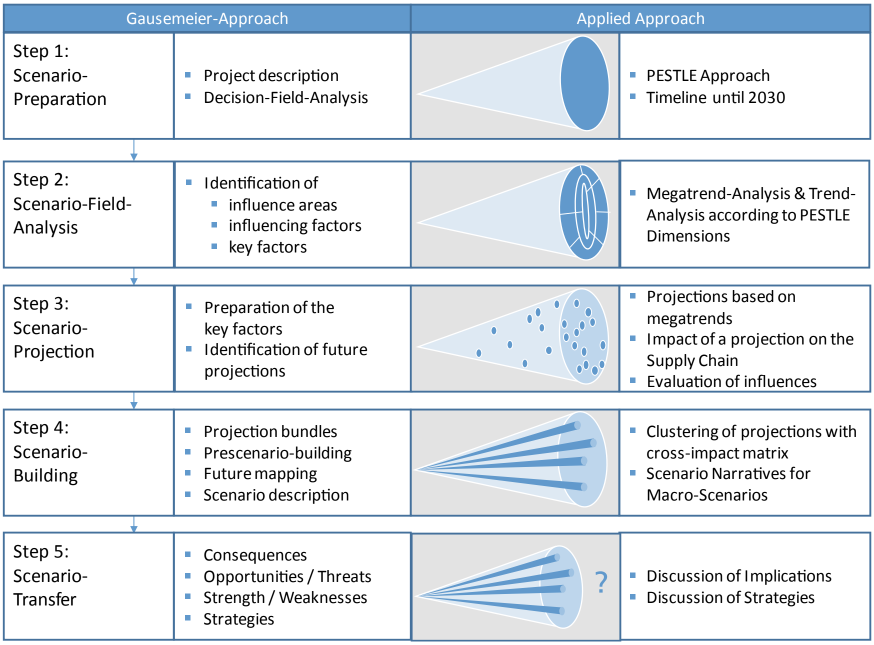

Fig. 1 Application of the Gausemeier approach (own representation following Gausemeier et al. 1995)

scenarios via cross-impact analysis resulting in a set of final scenarios. As the cross-impact evaluation is a pure mathematical approach, a qualitative approach enhances the methodology with a validation of the plausibility of each scenario. Accordingly, experts are invited to evaluate the probability of occurrence of each scenario and its impact on the supply chain. Finally, a storyline for each macro scenario details the scenario settings and conveys the differences of each scenario to the decision-making units. While reflecting on the impact of each scenario, conclusions have to be drawn on how to prepare for, or even influence, different alternatives. Step 5 is dedicated to scenario transfer that aims at developing appropriate strategies for each scenario.

As the first two steps (scenario preparation and field analysis) are described in Kalaitzi et al. (2020), the following sections detail step 3 (scenario projection) and parts of step 4 (scenario building). Sardesai et al. (2020) refines the scenario narratives and impact of each scenario on supply chains. Barros et al. (2020) provides the methodological approach for scenario transfer and supply chain strategies for each macro-scenario.

3 Scenario-Projection–Conception of Future Projections

The creation of future projections relies on previously identified trends and mega-trends. The six PESTLE dimensions set the framework and form subsections, each incorporating several so-called 'descriptors' (Gausemeier and Plass 2014). Descriptors express a neutral form of future topics and are characterised by diverging future projections. Future projections express a certain future state of a descriptor and describe possible circumstances that companies and societies might face. Most commonly, a descriptor comprises a positive, negative and neutral future projection.

The development of future projections for the descriptors is a decisive step in the scenario planning as they create the structural components for the upcoming scenarios. The significance and quality of the scenarios depend on it, and thus ultimately the success of the entire scenario project, too. Generally, future projections have to contain plausible future states and it is necessary to consider extreme but possible developments. At the same time, it is essential that each projection remains reasonable and conceivable, in the sense that a projection can be futuristic but needs to rely on valid arguments or requires justification by means of statistical developments (Gausemeier and Plass 2014). Careful attention has to be paid to the distinctness of the projections to ensure that the subsequent consistency check leads to reasonable combinations of projections and consistent scenarios. Hence, the projections have to fulfil the following criteria:

- Plausibility—a projection needs to be plausible to the scenario team.
- Dissimilarity—all projections have to be distinct from each other.
- Completeness—a set of projections within a descriptor has to provide a comprehensive set of possible developments.
- Relevance—each projection requires a check regarding its future relevance.

- Information content—each projection needs to add further value to the set of projections within a descriptor.

Table 1–Table 6 list the different descriptors and future projections that result from the underlying field analysis (see Kalaitzi et al. 2020; Daus et al. 2018). The projections are separated according to the six PESTLE dimensions.

Table 1 Overview of the resulting projections for the political dimension

Political dimension		
Political setting	Political concord in Europe	We experience a politically stable environment in Europe. States at the border region and trade partners are living in peace (Stiftung 2018)
	Constant development in Europe	The number of terrorist attacks is slowly decreasing due to stronger security enforcements (Stiftung 2018; EUROPOL 2017)
	Governmental collapse in Europe	Social unrest and conflicts characterize everyday life throughout European countries. Frequent strikes occur and terrorist attacks hinder economic growth (Stiftung 2017b)
Trade policies	Protectionism	We experience a policy of protecting domestic industries against foreign competition entailing a rise in trade policies such as tariffs, import quotas (de Kluyver 2010)
	Free trade	We experience a policy of open trade, not discriminating against imports from and exports to foreign competitors. Countries are interested in making trade as easy as possible (World Economic Forum 2016b)
Confederation	Contended Union	Asian, Latin American and other countries form state unions. EU Member States act as a single political, economic area promoting free movement of goods, services, capital and people (World Economic Forum 2016b)
	Unstable confederations	Some countries push for change and express their discontent with the confederation. Free movement and trade agreements remain (Stokes 2016)
	Fragmentation	The EU is going into crisis and several countries are leaving the confederation (Stiftung 2017a)

Table 2 Overview of the resulting projections for the economic dimension

Economic dimension		
Global trade shift	The pendulum shifts	Global market demand and trade shifts specifically to Asia. It is projected that new emerging economies such as Mexico and Indonesia will be larger than the UK and France by 2030 (WTO 2017)
	Steady Titans US and Europe	US and Europe manage to keep export trading volume high, and heavily invest in education and new technologies (PwC—Price Waterhouse Coopers 2015)
Global corporate structures	Think global, act local	An increase in wages in previously low-wage countries, and cost of shipping and custom fees, make local production attractive again. Companies follow market demand and primarily offer and source local products (Menon 2014)
	Rise of born-global firms	Digitalisation helps SMEs and start-ups to participate on a global level. Born-global firms are innovative in all areas of value creation, both technological and non-technological (Weerawardena et al. 2007)
Digital economy	Pure traditional economy	People object to digitalisation and accept limited online functionality due to privacy. Traditional physical goods such as hardcopies of books are preferred (Brynjolfsson and Kahin 2000)
	Traditional economy persists	The traditional way is upheld due to fear of data misuse and legal and political concerns limit development. Even though traditional business needs to cooperate with online platforms (such as for food delivery services or fashion), customers continue to e.g. eat and shop the conventional way (Laudon and Traver 2014)

(continued)

Table 2 (continued)

Economic dimension		
	Platform economy	Expanding digital economy B2B by developing more collaborative platforms enabling an easy share and utilisation of resources (hubs, terminals, etc.) (PwC—Price Waterhouse Coopers 2017b)
Financial innovations	Bank and Fintech collaboration	The rise of Fintech companies transforms bank institutions and other sectors. Start-up companies compete with traditional banking by focusing on digital processes and innovation, thus enabling better customer interactions (PwC—Price Waterhouse Coopers 2017a)
	A world without banks	Smart ledgering enables a new kind of trading. It is possible for each individual to create their own virtual currency. Transactions are secured via new technologies, e.g. blockchain. Using secure web services, devices submit financial transactions autonomously (Karathodorou; Fintechnews Singapore 2016)
	Big 5 are the banks of the future	Trusted third party services develop their own digital currencies, taking over the "traditional" currencies. E.g., the big five IT companies offer their own currencies to facilitate seamless payment between both people and devices (Shah et al. 2016)

Table 3 Overview of the resulting projections for the social dimension

Social dimension		
Demographic change	Ageing population and acceleration of disparities	Due to longer and healthier lives in developed countries, a significant increase in older populations can be assumed (Krys and Fuest 2017)
	Awareness of inequalities and wealth redistribution	New forms of solidarity, social engagement and civil participation develop within society supporting fast integration of migrating young people (Krys and Fuest 2017)
Urban living	Smart regions	Some people leave the cities to live in the countryside. While people continue to work in cities, they look forward to a break in the countryside (Zelt et al. 2017)
	Smart cities	Smart cities with free Wi-Fi in all public spaces, where children learn how to program apps in elementary school, goods are delivered to homes within hours, and e.g. street lighting is provided on demand (Zelt et al. 2017)
Consumption patterns	Much and cheap	We experience a throwaway society in which people focus on convenient and mass products (Kharas 2017)
	Consumption awareness	Customers receive detailed information about products they buy. An ecological mind-set determines consumption and products within other sectors like transportation (Kharas 2017; Eurostat 2016)
	DIY Society	Motivated by increased consumption awareness, a perceived lack of quality from available offerings and the need for customisation, people become strongly involved in the production process (Wolf and McQuitty 2011)

(continued)

Table 3 (continued)

Social dimension		
	Individualised consumption	A transition towards small scaled households affects the quantity sizes demanded and the way products are requested, purchased and consumed in each household (Agriculture and Agri-Food Canada 2010)
Customer orientation	Individualism—focus on variety	Personalised purchases are offered in categories like holidays, clothing and furniture. Companies postpone their production until the latest point possible to allow individual customisation (Deloitte 2015)
	Collectivism—focus on the crowd	Social networks strongly influence buying behaviour and hence, companies have to adapt quickly on a large scale (Frank et al. 2015)
Knowledge-based economy	Investments equalize the labour market	The investment in new production structures and new facilities partly equalizes low skilled job opportunities lost due to autonomisation (Lorenz et al. 2016)
	Rapid changes cause unemployment	Several industry sectors are affected by autonomisation, which leads to a high overall rate of unemployment, a loss of seven million jobs in transportation alone is predicted (Lorenz et al. 2016)

Table 4 Overview of the resulting projections for the technological dimension

Technological dimension		
Digital transformation	Rapid advancement of digitalisation	The overall technological development evolves fast in an open manner and enables small and multinational companies to profit from products and services that are increasingly personalised, data-intensive and context-aware (World Economic Forum 2016a)
	Obstacles restrain digital transformation	Performance improvements through digital transformation seem obvious, but can seldom be verified and lack proof of evidence (Bouee and Schaible 2015)
	Digital stagnation	Only a few companies attempt to promote digital transformation further but are struggling with a lack of compliant regulations and political support (Bingley et al. 2016)
Autonomous systems	Dynamic development of autonomous technologies	Cyber-physical systems enable efficient communication and control by transferring and exchanging data in real time. An increased exploitation of these technologies leads to a highly automated, autonomous environment (Bingley et al. 2016)
	Innate reluctance to accept autonomous technologies	Since an autonomous technology requires suites of expensive sensors, the average cost of this technology remains high. In addition, regulations prevent the full exploitation of their potentials (Omohundro 2014)
Alternative energy generation, storage and usage	Established electrification technologies and green systems	New power grid solutions and grid transformations overcome technological limitations. This enables a smart grid environment with distributed energy generation and powerful storage systems (Howell et al. 2017)

(continued)

Table 4 (continued)

Technological dimension		
	Ongoing electrification and alternative energy endeavours	Green systems used for power generation, energy storage and transportation, such as hydrogen power cells and biomass, are gradually applied in industrial and social sectors (McKinsey 2010)
Decentralised connection of information and physical devices	Dominance of global players	Only global players have significant resources, global data sets and institutional know-how to harness for their digital transformation (DHL Customer Solutions and Innovation 2016)
	Start-ups and SMEs take up business	Many small and medium-sized enterprises (SMEs) and start-ups attack traditional markets, due to the democratisation of technology, increased access to funds and a rising entrepreneurial culture (Coleman et al. 2016)
Disruptive production technologies	Continuous exploitation of disruptive technologies	Suppliers of disruptive technologies experience exponential growth rates. Existing technologies are improved and additional solutions are developed in a rapid and continuous manner (Jiang et al. 2017)
	Coexistence of conventional and disruptive technologies	Conventional technologies and disruptive technologies coexist in industry. A widespread implementation of disruptive technologies is missing due to high associated costs, lack of expertise and uncertainty of quality (Bingley et al. 2016)

Table 5 Overview of the resulting projections for the legal dimension

Legal dimension		
Consumer Protection Laws	Promotion of laws and full product transparency	Safety and approval regulations for new products are in place and constantly monitored. For cross border transactions, the required general legislation has been adopted and consumers' personal data are strictly protected in the EU (PwC—Price Waterhouse Coopers 2011)
	Legislation is lagging behind dynamic market development	Arising trends (e.g. sharing economy, digital market) lack legislative clarity and are still key priorities for regulations and consumer protection laws in Europe (Rhodes 2017)
Intellectual property laws	Full security for inventors and data providers	Secure peer-to-peer data networks allow regulated data transfer supported by politics, businesses and research (Mittal et al. 2017)
	Low confidentiality for data and market participants	Comprehensive data exchange via conventional business platforms, especially with potential competitors, is a challenge since core data and business secrets are exposed and liability regulations are missing in case of infringement (PwC—Price Waterhouse Coopers 2016)
Social and environmental regulations	Comprehensive regulatory framework	Standards exists on how frameworks and reports for setting regulations are communicated. New legislator decisions facilitate business and set decisive, easy to implement regulations in terms of corporate responsibility (CR) and sustainability (Governance and Accountability Institute 2016)
	Heterogeneous regulations	Standards and widely accepted regulatory frameworks are missing in Europe as well as worldwide (Ceniga and Sukalovaba 2015)

Table 6 Overview of the resulting projections for the environmental dimension

Environmental dimension		
Climate impact	Our environment is recovering	Rapid improvements in energy efficiency and a greater share of zero- and low-carbon energy supply reduce and maintain global warming at an environmentally acceptable rate (European Commission 2016). The number of natural disasters stabilises and even declines slightly. Incidents of pandemics or epidemics and general infectious diseases appear less frequently (WHO 2004)
	Our environment on the brink	Rising atmospheric CO_2 concentration and rising temperatures reach new peaks as time passes. Crucial signs for continued climate change (Schwartz et al. 2014). The frequency of pandemics and epidemics increases along with the deterioration of the environment. Natural hazards like floods and hurricanes become very common and support the spread of epidemics
Environmental resource management	Countering resource depletion	Improvements to the collection, treatment and recycling of waste, particularly of electronics and plastics at end of life, contribute to circular economy endeavours (European Commission 2018)
	Rise in depletion of natural resources	Ever-increasing global population, economic growth and demand for resources from affluent consumers contribute highly to severe ongoing depletion of resources (Krys and Fuest 2016)

4 Scenario Building—Creation of Scenarios

The major challenges in scenario building comprise, on the one hand, the evaluation of the credibility of different combinations of projections and, on the other hand, the aggregation of coherent combinations of projections to a scenario. To overcome these challenges, the scenario building technique within scenario planning contains powerful tools to identify contextual challenges and opportunities. The technique highlights the implications of possible future systems and projects consequences of choices or policy decisions (Amer et al. 2013).

The tools and methods of scenario building evaluate possible combinations of future projections. Each resulting set of future projections forms a scenario. This can result in a high number of different scenarios, some of them with a low credibility of interrelation. Such contradictions are referred to as inconsistencies (Gausemeier and Plass 2014). This implies that a scenario has a tendency to implausibility in cases of a high number of inconsistent future projections. It is therefore necessary to evaluate the consistency of each scenario as it acts as a decisive factor for its credibility.

There are several methodologies to evaluate the consistency of a scenario. The simple consistency analysis itself has certain constraints and practice has demonstrated that a simple consistency analysis does not sufficiently limit the spectrum of possibilities. To further restrict the spectrum of possibilities, Theodore Jay Gordon and Olaf Helmer developed a Cross-Impact Analysis (Gordon 1994), later extended as a Cross-Impact Balance Analysis (CIB). Similar to a consistency analysis, a CIB assesses the relationships between the factors in pairs. In contrast to the consistency analysis though, a CIB does not assess the concurrence of two future projections, but the direct effect that the occurrence of one future projection has on the other. A CIB therefore works with causal information (Weimer-Jehle 2009) and utilises qualitative insights of the individual relationship between the factors of the network thus constructing consistent images of its overall behaviour (ZIRIUS 2020). The scenario technique is one of the typical applications of CIB.

Depending on the method used, the impact assessment is either carried out along with an evaluation of probabilities, or, similar to consistency analysis, by qualitative assessments on an ordinal scale. Mathematical simulations or calculations support the evaluation process which has given cross-impact analysis the reputation of oversized mathematisation among qualitatively oriented scenario analysts. Still, the mathematical approach facilitates the implementation in a tool such as the CIB tool developed under the leadership of Dr. Weimer-Jehle at the University of Stuttgart. The tool is available on an open source basis, in order to benefit from the advantages of this methodology (see https://www.cross-impact.de/english/CIB_e.htm).

4.1 Evaluation of Impacts of Future Projections via the Cross-Impact Matrix

The methodology of the Cross-Impact Matrix, as part of the CIB, is based on a matrix that plots the future projections, once in the ordinate and once in the abscissa. The evaluation of the impact between two future projections takes place in a group of experts who evaluate and assess the direct impact between two future projections. The group of experts should consist of people with a diversified background to ensure a broad view on the evaluation of the projections. As an example, the evaluation can consider the following scale:

−2 = strong impeding influence, i.e. future projection A1.1 has a strong inhibiting influence on the future projection A2.1. A common occurrence in a scenario has to be argued.
−1 = moderate impeding influence, i.e. future projection A1.1 has a moderate inhibiting influence on future projection A2.1.
0 = neutral or independent influence, i.e. the respective future projection does not affect the other.
1 = moderate supporting influence, i.e. future projection A1.1 has a light supporting effect on future projection A2.1. Both future projections may well occur in a scenario.
2 = strong supporting influence, i.e. the future projection A1.1 has a strong supporting effect on future projection A2.1. If future projection A1.1 occurs in a scenario, future A2.1 can also be expected to be in the same scenario.

In contrast to the consistency analysis, the CIB matrix must be filled in completely in order to be able to express the causality of the relationships (Weimer-Jehle 2006, 2008). An extract of the CIB matrix is shown in Fig. 2 along with the applied procedure.

It is recommended to invite several expert groups to evaluate the Cross-Impact Matrix in order to ensure objectivity. Resulting matrices can be consolidated by using a scaling up mechanism. This means that the target matrix consists of the sum of the individual judgement matrices. By comparing two matrices, this extends the range of judgement to −4 to 4. Scaling-up has no influence on the later evaluation, but allows a differentiated evaluation.

4.2 Development of Future Scenarios with the Cross-Impact Balance Analysis

The CIB uses an inductive approach to form different sets of scenarios. The consistency analysis is the core of the CIB procedure. The method assesses the plausibility of the combined future projections within a scenario. Based on the output of the

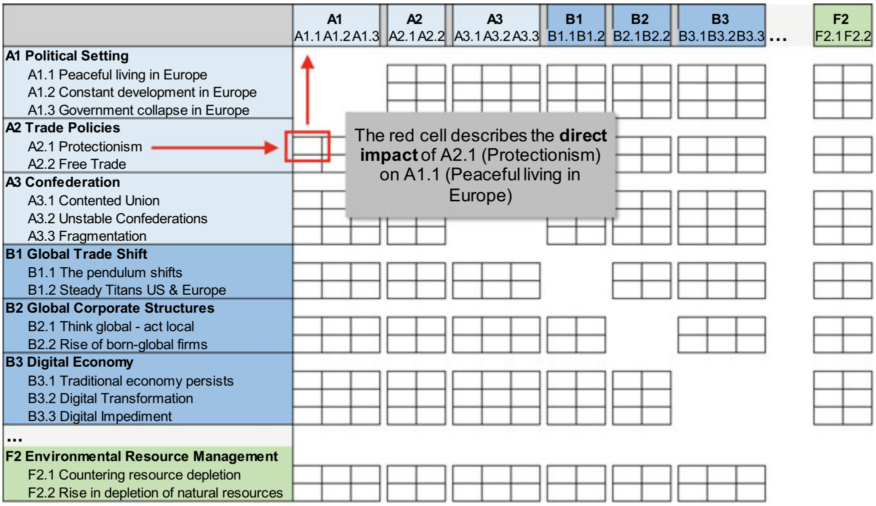

Fig. 2 CIB matrix to support judgements

cross-impact matrix and its impact balances, all consistent clusters of future projections are considered as suitable scenarios (Gausemeier et al. 1988). For this purpose, all possible scenario sets are evaluated according to their consistency and their logical fitness. The general procedure taken within the Gausemeier approach is shown in Fig. 3.

In order to achieve consistent and plausible scenarios, impact scores serve to conduct consistency and plausibility checks in the CIB. They are calculated for each future projection by selecting the rows (future projections) that belong to the analysed projections of one descriptor bundle and then calculating the column sum.

The impact scores of a descriptor define its impact balance. As an example, Fig. 4 shows three descriptors with two future projections each. The figure reflects two scenarios; each scenario includes one future projection of each descriptor. Within Fig. 4, the scenario in each table is highlighted in grey. Scenario 1 is represented by 'Free Trade', 'High Capability' and 'Digital Impediment'. Scenario 2 consists of the future projection 'Free Trade', 'High Capability' and 'Digital Transformation' (instead of 'Digital Impediment'). In Scenario 1, the impact score for 'Free Trade' is calculated by adding the numbers at the vertical intersection with 'High Capability' and 'Digital Impediment', $0 + (-1) = -1$. In Scenario 2 though, the impact score for 'Free Trade' results in $0 + 1 = 1$ (please refer to encircled numbers within the figure).

In accordance with the CIB consistency principle, the scenario set has to represent the maximum impact score within an impact balance. Hence, for a consistent scenario, the chosen future projections have to achieve the maximum impact score within each descriptor. Within Fig. 4, the future projections of each scenario are highlighted with a black arrow on the top of the impact score ('Free Trade', 'High

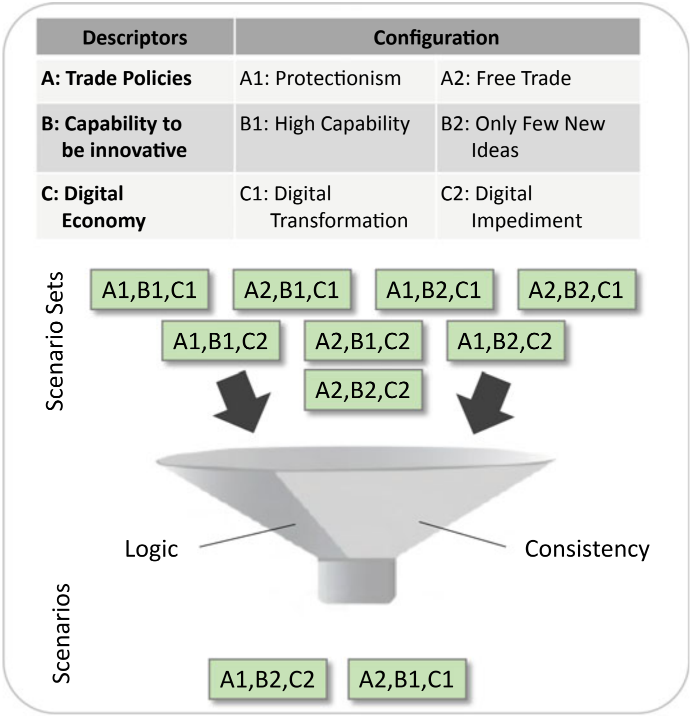

Fig. 3 Achievement of consistent projection bundles

Capability' and 'Digital Impediment' for Scenario 1, 'Free Trade', 'High Capability' and 'Digital Transformation' for Scenario 2). The maximum value of each descriptor is highlighted with a black arrow below the impact score ('Protectionism', 'Only Few New Ideas' and 'Digital Transformation' for Scenario 1, 'Free Trade', 'High Capability' and 'Digital Transformation' for Scenario 2). Once all arrows point to the same projection, the scenario counts as consistent. This is the case in Scenario 2 (lower table in Fig. 4), where all maximum values of the impact scores correspond to the projection within the scenario set. On the contrary, according to CIB, Scenario 1 is considered as inconsistent as none of the scenario assumptions fits to the maximum impact balances.

The CIB offers various evaluation options for determining consistent scenarios. Scenario 2 considered in the example above applies "strong consistency". This option returns only those scenarios in which the scenario assumption corresponds to the highest impact score in any case (Weimer-Jehle 2008). To increase the diversity of the resulting scenarios in order to cover a wider scenario space, it is also possible to loosen the consistency principle and to allow for a certain inconsistency value while retaining the validity and plausibility of this scenario (Weimer-Jehle 2018).

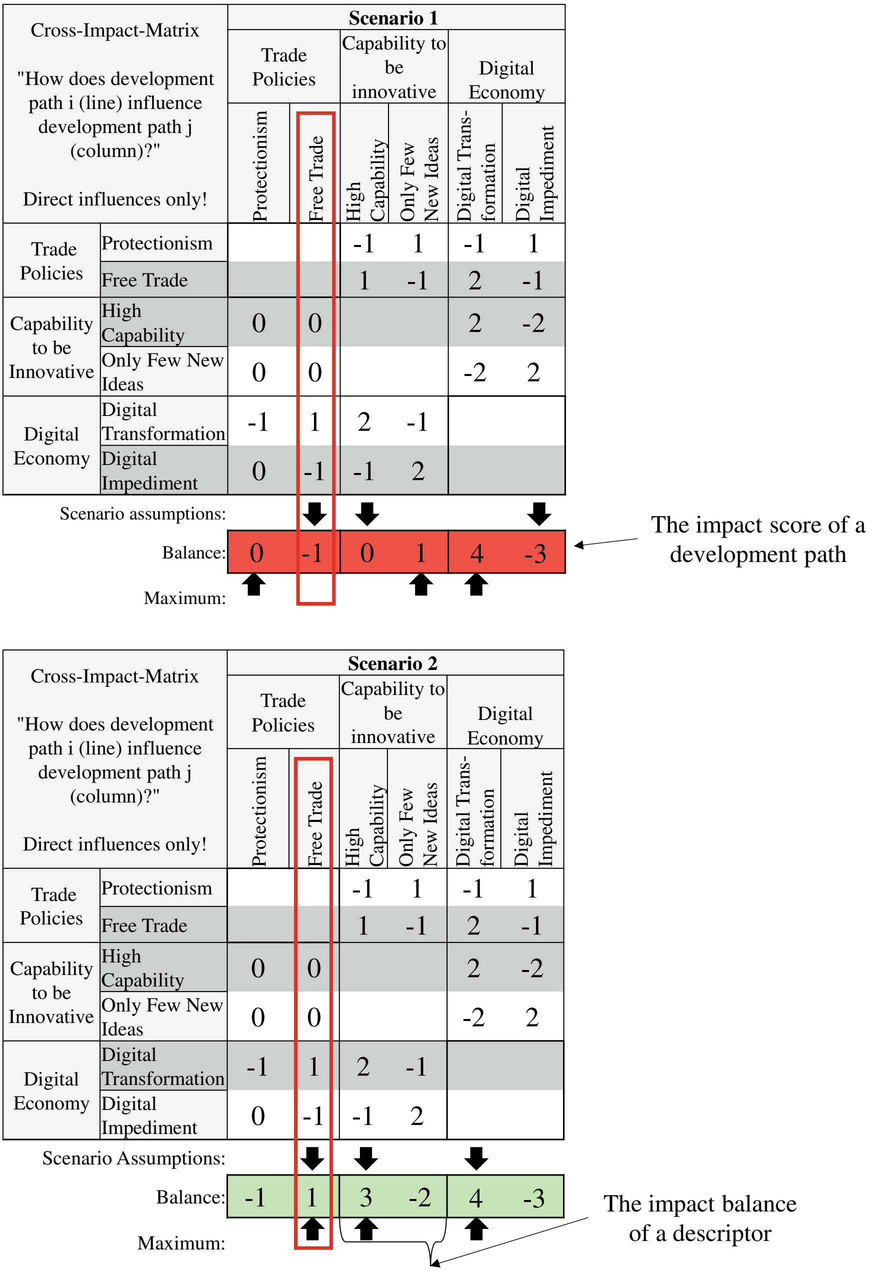

Fig. 4 Example CIB consistency calculation

Its simple comprehensibility and its potential to work through a complex network of interdependent factors make consistency analysis an attractive compromise between simplicity and analytical depth.

4.3 Resulting Set of Scenarios

In the underlying case, around 63 million possible projection bundles had to be evaluated. For the consistency check conducted by the CIB tool, several consistency criteria were defined in order to reduce the range of solutions. This has resulted in twelve consistent scenarios. Two of the resulting scenarios show an overall progressive development. Foremost, a stable political and economic environment characterizes these scenarios (Aspirant and Proceeding). Regressive overall development characterizes two further scenarios represented by a politically and economically unstable situation, as well as lagging legislation and poor environmental conditions (Escapism and Endanger). All other scenarios can be classified in between, they show mixed developments. Figure 5 displays the scenarios and the configuration of the projections.

4.4 Validation and Selection of the Scenarios

After the quantitative method of locating consistent scenarios has been carried out, it is necessary to validate the scenarios qualitatively to increase their interpretability and validity. Following the methodology, it is necessary to evaluate the probability of occurrence of a scenario and its impact strength on the decision field. In the underlying case, the evaluation assesses the impact strength of the macro scenario setting on supply chains. The latter evaluates the potential pressure for changes on current supply chain settings.

An expert-workshop is chosen to fulfil this qualitative task. Again, with regard to the topic concerning the creation of future scenarios, it is recommended to select experts with a diverse background and from different industrial sectors. A discussion round between the experts helps to formulate scenario narratives. The results of the evaluation of the scenarios are then transferred into a probability-impact-matrix thus displaying the overall distribution of the scenarios. Figure 6 shows the result for the probability and impact evaluation of the retrieved scenarios.

The outcome of the assessment serves to refine the results of those scenarios which are probable and plausible and necessitate a change to future supply chains. As recommended in the literature, the number of scenarios has to be restricted to allow thorough further analysis with detailed scenario narratives. Bradfield et al. (2005) recommend a scenario set of three to six scenarios using a quantitative approach combined with expert judgements. The final number of selected scenarios is highly dependent on the number of future projections considered and their uncertainties (Amer et al. 2013).

	aSPIRANT	PrOCEEDINg	oFFsET	EpOCHAL Brink	SPIN DOWN	CIRCuiT
Political Setting	Political concord in Europe		Constant development in Europe			
Trade Policies	Free Trade					Protectionism
Confederation	Contended Union		Unstable Confederations		Fragmentation	Unstable Confederations
Global Trade Shift	Steady Titans US & Europe		The pendulum shifts			
Global Corporate Structures	Rise of born-global firms	Think global, act local		Rise of born-global firms	Think global, act local	
Digital Economy	Platform economy		Pure traditional economy	Traditional economy persists	Pure traditional economy	
Financial Innovations	Big 5 are the banks of the future	Bank and Fintech collaboration	Big 5 are the banks of the future		A world without banks	Big 5 are the banks of the future
Demographic Change	Awareness of inequalities and wealth redistribution			Ageing pop. & acceleration of disparities	Awareness of ineq. & wealth redistrib.	Ageing pop. & acceleration of disparities
Urban Living	Smart regions	Smart cities				Smart regions
Consumption Patterns	Consumption awareness	DIY Society	Much and cheap		DIY Society	
Customer Orientation	Collectivism - Focus on the crowd	Individualism – Focus on variety	Collectivism - Focus on the crowd		Individualism – Focus on variety	
Knowledge-based Economy	Investments equalise the labour market			Rapid changes cause unemployment	Investments equalise the labour market	Rapid changes cause unemployment
Digital Transformation	Rapid advancement of digitalisation		Obstacles restrain digital transformation			
Autonomous Systems	Dynamic development of autonomous technologies		Innate rel. to accept aut. tech.	Dynamic dev. of autonomous tech.	Innate reluctance to accept autonomous technologies	
Altern. energy generation; storage & usage	Established Electrification Technologies and Green Systems		Ongoing electrification and alternative energy endeavours			Est. Elec. Tech. & Green Sys.
Decentralised connection of information and physical devices	Dominance of Global Players	Start-ups and SMEs take up business	Dominance of Global Players		Start-ups and SMEs take up business	Dominance of Global Players
Disruptive Production Technologies	Continuous exploitation of disruptive technologies		Coexistence of conventional and disruptive technologies			
Consumer Protection Laws	Promotion of laws and full product transparency		Legislation is lagging behind dynamic market development			
Intellectual Property Laws	Full security for inventors and data providers		Low confidentiality for data and market participants			
Social and Environmental Regulations	Comprehensive regulatory framework		Heterogeneous regulations			
Climate Change	Our environmenti s recovering		Our environment on the brink			Our environmenti s recovering
Environmental Resource Management	Countering resource depletion		Rise in depletion of natural resources			Countering resource depletion

Fig. 5 Overview of the twelve selected scenarios

As displayed in Fig. 6, the assessment resulted in six scenarios that force a strong to medium change on the supply chain (impact factor > 3) and have a rather high probability (>35%).

<table>
<tr><th></th><th>OUTsET</th><th>DiThER</th><th>Almost BLACK</th><th>UNEasE</th><th>EScAPiSm</th><th>ENDANGEr</th></tr>
<tr><td>Political Setting</td><td colspan="4">Constant development in Europe</td><td colspan="2">Governmental collapse in Europe</td></tr>
<tr><td>Trade Policies</td><td colspan="4">Protectionism</td><td>Free Trade</td><td>Protectionism</td></tr>
<tr><td>Confederation</td><td colspan="6">Fragmentation</td></tr>
<tr><td>Global Trade Shift</td><td colspan="6">The pendulum shifts</td></tr>
<tr><td>Global Corporate Structures</td><td colspan="6">Think global, act local</td></tr>
<tr><td>Digital Economy</td><td>Pure traditional economy</td><td colspan="2">Platform economy</td><td>Traditional economy persists</td><td>Platform economy</td><td>Traditional economy persists</td></tr>
<tr><td>Financial Innovations</td><td>Big 5 are the banks of the future</td><td>Bank and Fintech collaboration</td><td>Big 5 are the banks of the future</td><td>Bank and Fintech collaboration</td><td colspan="2">A world without banks</td></tr>
<tr><td>Demographic Change</td><td>Awareness of ineq. & wealth redistrib.</td><td colspan="5">Ageing population and acceleration of disparities</td></tr>
<tr><td>Urban Living</td><td colspan="6">Smart cities</td></tr>
<tr><td>Consumption Patterns</td><td>Consumption awareness</td><td colspan="4">DIY Society</td><td>Much and cheap</td></tr>
<tr><td>Customer Orientation</td><td colspan="5">Individualism – Focus on variety</td><td>Collectivism - Focus on the crowd</td></tr>
<tr><td>Knowledge-based Economy</td><td>Investments equalise the labour market</td><td colspan="3">Rapid changes cause unemployment</td><td>Investments equalise the labour market</td><td>Rapid changes cause unemployment</td></tr>
<tr><td>Digital Transformation</td><td>Digital Stagnation</td><td colspan="5">Obstacles restrain digital transformation</td></tr>
<tr><td>Autonomous Systems</td><td>Innate rel. to accept aut. tech.</td><td colspan="2">Dynamic development of autonomous technologies</td><td>Innate rel. to accept aut. tech.</td><td colspan="2">Dynamic development of autonomous technologies</td></tr>
<tr><td>Altern. energy generation; storage & usage</td><td colspan="2">Established Electrification Technologies and Green Systems</td><td colspan="4">Ongoing electrification and alternative energy endeavours</td></tr>
<tr><td>Decentralised connection of information and physical devices</td><td>Dominance of Global Players</td><td>Start-ups and SMEs take up business</td><td>Dominance of Global Players</td><td colspan="2">Start-ups and SMEs take up business</td><td>Dominance of Global Players</td></tr>
<tr><td>Disruptive Production Technologies</td><td>Coexistence of conv. and disruptive tech.</td><td colspan="2">Continuous exploitation of disruptive technologies</td><td>Coexistence of conv. and disruptive tech.</td><td>Continuous exploitation of disruptive tech.</td><td>Coexistence of conv. and disruptive tech.</td></tr>
<tr><td>Consumer Protection Laws</td><td colspan="6">Legislation is lagging behind dynamic market development</td></tr>
<tr><td>Intellectual Property Laws</td><td colspan="6">Low confidentiality for data and market participants</td></tr>
<tr><td>Social and Environmental Regulations</td><td colspan="6">Heterogeneous regulations</td></tr>
<tr><td>Climate Change</td><td>Our environment on the brink</td><td>Our environmenti s recovering</td><td colspan="4">Our environment on the brink</td></tr>
<tr><td>Environmental Resource Management</td><td>Rise in depletion of natural res.</td><td>Countering resource depletion</td><td colspan="4">Rise in depletion of natural resources</td></tr>
</table>

Fig. 5 (continued)

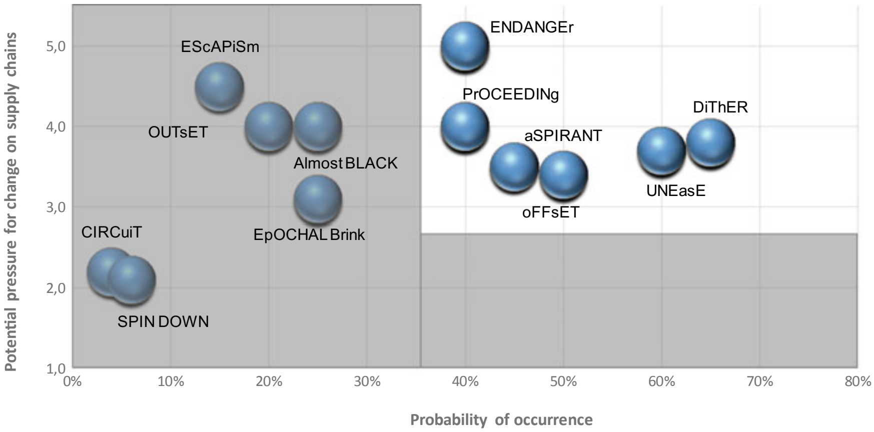

Fig. 6 Overview of the assessment of the scenarios and scenario selection

5 Conclusion

Various methodologies can be applied to create future developments. This chapter describes a methodology that integrates quantitative and qualitative approaches. The applied methodology differs from a pure prognosis or forecast. Instead, it provides several possible future scenarios on how the macro surroundings for supply chains might look in a time horizon until 2030. This approach has the advantage that deduced policy decisions or company strategies consider possible changes in future conditions. This approach results in the selection of six validated scenarios that have a great impact on the design of future supply chains. From a managerial perspective, the results enable early preparations to be carried out for various potential development paths until 2030. Both countries and companies can benefit from this: since alternative plans are available on shorter notice, necessary measures to strengthen competitiveness can be initiated much earlier and in a more targeted manner.

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Future Scenario Settings for Supply Chains

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Abstract Trends and future developments make it necessary to discuss the future, but it is their bundling that forms a future scenario. This chapter describes six identified and verified macro-scenarios for future industry specific settings, which are shaped by various socio-economic, political, technological and environmental future developments. The description of each macro-scenario allows conclusions to be

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drawn on supply chain developments such as circular aspects, trade impacts or necessary supply chain structures. Each future scenario is set in a conceptual framework that provides the context and meaning of possible futures and enables companies to prepare and adjust their strategies accordingly.

Keywords Scenario description · Narratives · Future supply chains · Logistics · Scenario analysis

1 Introduction to a Scenario Description

A scenario description represents a possible future development in narrative form which denotes its main characteristics (Meinert 2014). It portrays causal relationships that explain how, from the vantage point of the present, a particular future in a certain story setting has been derived. In so doing, a scenario has to be distinguished from a prognosis as scenarios indicate different possible states of the future without defining just one single status. Scenarios outline aspects of the future for public (Wilkinson and Eidinow 2008) and private institutions or private interests (Amer et al. 2013). Thus, the generated scenarios help organisations to prepare for eventualities and potential circumstances and to ensure innovative and flexible development (Amer et al. 2013).

The creation of narrative descriptions conveys the content of the diverse future developments within a scenario. The description exposes all the progressive as well as the regressive future projections that are integrated while at the same time characterising the main features of each scenario. This enables a common understanding and promotes scenario communication. It furthermore displays that diverse sets of projections can lead to unexpected future outcomes. Discussants can draw their conclusions for each scenario description. The extraction of the main characteristics of each scenario enables the future to be conveyed in such a way that it is differentiated and rich in contrasts (Meinert 2014).

Figure 1 shows an exemplary set of scenarios from Meinert (2014). The example shows scenarios represented within a picture to explain the content and the overall development of the scenarios. Each picture highlights the relevant and differentiating settings within the respective scenario.

However, scenarios can be described not only by means of a picture, but also in the form of a narrative. In both cases it is important that a scenario description assists the user and the audience with their explanations. In this manner, conclusions can be drawn on how to prepare for, or even influence the different scenario alternatives identified in the scenario-building process. Weather scenarios as shown in Fig. 2 show a simple example for describing scenarios and the resulting strategies on how to approach the respective scenario in case it occurs.

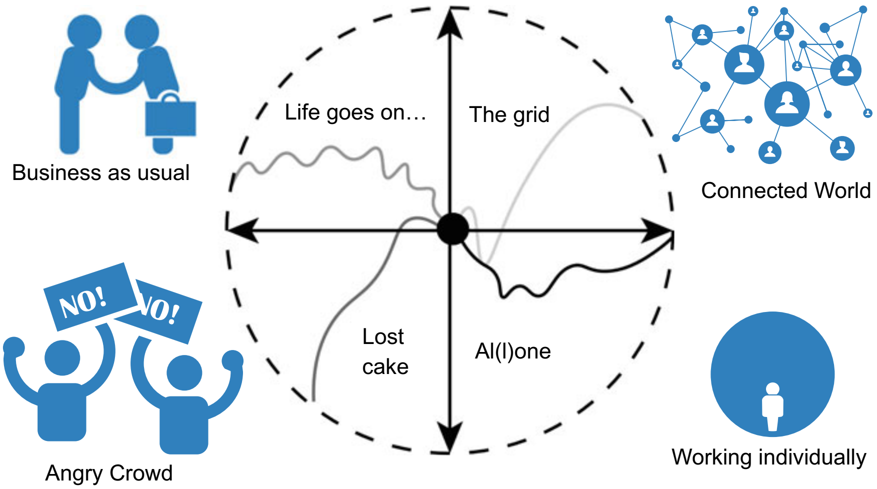

Fig. 1 Exemplary scenario naming and picture creation (adapted from Meinert 2014)

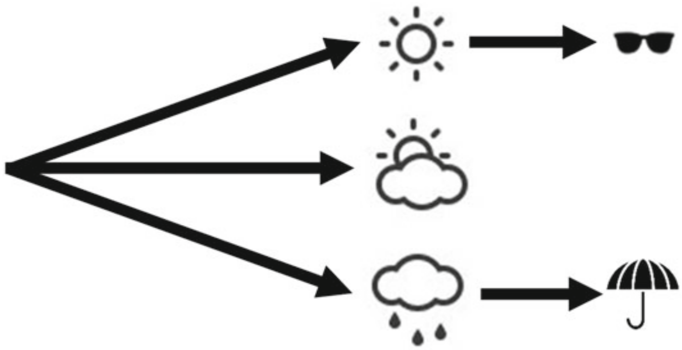

Fig. 2 Description of future projections based on future scenarios

2 Macro-Scenarios for Future Supply Chains

As scenario descriptions exemplify the relationship between the future projections, they serve to visualise each scenario, thus providing a common understanding. To generate this common understanding, each future projection within a scenario has been discussed in detail within an expert community. Different viewpoints have been considered (1) along with the interrelation between the future projections and (2) with regard to their impact on supply chains.

The result of these discussions are consolidated below and form six heterogeneous macro-scenarios. The description of each macro-scenario reveals the circumstances and surroundings future supply chains have to deal with by 2030 (based on results achieved in Sardesai et al. 2020). Each macro-scenario details its inherent future projections and their corresponding challenges with respect to supply chain management.

All macro-scenarios contain an explanation of their main characteristics and a description of the respective scenario settings. The description concludes with a table containing the most relevant projections for each PESTLE dimension (PESTLE—political, economic, social, technological, legal, and ecological). The possible impacts on the supply chain structure and processes complement the scenario setting.

The following scenario descriptions are arranged according to the similarity of their overall development and their projections. The narratives start with a scenario that outline an overall progressive development, aSPIRANT, and finalise with a scenario with rather stagnating and retrogressive developments, which has been named ENDANGEr.

2.1 "aSPIRANT"—Strong PartnershIp enables homogeneous fRameworks Allowing a sustainable aNd Technological Development

aSPIRANT—General setting

aSPIRANT represents a rather positive view of future developments in all PESTLE dimensions. This scenario particularly entails the following aspects:

- Stable political and economic environment supports technological developments
- Sustainable and prosperous societies in EU that lead to social, technical and economic development
- Social balance is influenced by social media communities
- Global enterprises have widely implemented digital technologies and the tech start-ups are the economic winners.

A stable political and economic environment within the EU and its neighbouring countries characterises this scenario. Common agreements allow for coordinated rules and regulations that are valuable in economic and trading risk situations such as pandemics and natural disasters. Free trade agreements involving the EU and other economic unions support and facilitate the exchange of goods. The EU remains strong in exports and intensifies the role as a net investor in the world. As the political setting allows quick adaptations to regulations, there are clear regulations for handling data, thus creating transparency and IP-security. In addition, the fast and widespread progress of digitalisation supports the digital economy. The advancements of collaborative platforms make it easy to share and utilize resources. New digital business models are emerging in many different sectors. Big companies are the first movers as they have the resources to invest in developing technologies, followed by the tech start-ups that complement the industrial sectors with new services such as Fintech Services, and upcoming platform strategies. These new services innovate complete industrial sectors.

The political and economic setting supports technological developments. Emerging technologies such as advancements in artificial intelligence (AI) assist humans by undertaking autonomous planning and handling tasks. White-collar tasks change from actual decision-making to the supervision of AI-based decision-making systems. Increased exploitation of these technologies leads to a highly automated and autonomous environment. Suppliers of disruptive technologies experience exponential growth rates and existing technologies improve quickly and continuously.

Social networks strongly influence consumer behaviour, thus, companies have to adapt quickly on a large scale. Residents of the EU are more ecologically aware and pay attention to the origin of products as well as their recycling potential. This mindset leads inter alia to a preference for living in the suburbs. Fast transportation and innovation in the mobility sector support this lifestyle development, and hence, those developments strongly influence the economy. Since fossil fuels are depleting as time goes by, renewable electricity generation, transmission and distributed energy resource systems become even more relevant. At the same time, new power grid solutions and grid transformations overcome technological limitations and create a smart grid environment with distributed energy generation and powerful storage systems. Table 1 comprises the individual future projections for the aSPIRANT scenario.

Table 1 Elements of the aSPIRANT scenario

Political concord in EU; widespread free trade; stable alliances
US and EU as global trade leaders; digital platform economics; tech-giants dominate financial sector; globalised companies benefit
Sustainable consumer behaviour; social balance; adjusted labour market; living in smart regions
Digitalization, Industry 4.0 and “green systems” far advanced; predominantly large enterprises push disruptive developments
Legislative keeps pace with technological development
Climate protection successful; resource wastage curbed

aSPIRANT—Effects on supply chain

Regarding supply chain structure, harmonious political and economic development provides good conditions for strategic agreements across several states. At the same time, the fast technological development as well as the development of new production technologies affect the structure of supply chains. New business models are required, firstly to adapt to advances in the digitalisation and platform economy and secondly to allow for ecological development in terms of circular economy. Specifically, more agile and circular supply chain structures are required to manage the product life cycle in a circular manner, paying attention to different types and quantities of waste. Product design needs to consider this circularity of feedstock along with its supply chain management. In addition, frequent adaptations to the supply chain structure are needed to support the increasing demand for individualised products and to adapt to technological innovations.

In terms of processes, the political harmony combined with contented unions result in smooth and fast cross-border supply chains. With regard to digitalisation and the use of platform strategies, new digital processes are required to respond to the technology enabling faster and secured information flows. New services and financial payment options enable the implementation of supply chain finance (SCF) methods. Digitalisation provides algorithms that plan supply chains holistically and embrace SCF concepts. Along with the fast legal changes within this scenario, a revision of the supply chain processes is frequently required to fulfil the new and rapidly advancing laws. The common agreements and cooperative approach within the European Union enable fast recovery from natural disasters and pandemic events by supporting the fast ramp up of supply chain capacities and structures. In terms of resources, the advancements in digitalisation and new process technologies necessitate a significant effort by research and development (R&D). In addition, new employment or technological settings are required to deal with recycling and reusing processes across the globe to support the envisaged innovations successfully.

2.2 "PrOCEEDIng"—POlitical CohErEnce, Disruptive technologies and Individualised consumerism facilitate an innovative business development

PrOCEEDIng—General setting

The PrOCEEDIng scenario provides positive and harmonious overall development and embraces the following main developments:

- Stable political and economic environment with prospering medium sized businesses and start-ups which can adapt well to local markets and enable climate protection
- Customers act responsibly, but with a distinct demand for individualisation and living in smart megacities

- Social, technical and economic developments are progressing in parallel and set a homogenous framework in a highly digitised world.

Overall, PrOCEEDIng describes a very harmonious picture of the future with a stable political and economic environment. As political and economic settings allow for quick adaptations to legal regulations, new technological developments rise significantly. Start-ups and SMEs take advantage of this ideal setting by focusing on niche markets and lean organisational structures. In addition, digitalisation is evenly integrated into the business environment and permeates all aspects of society. This empowers advancements in autonomous planning and new emerging technologies assist humans in handling tasks at work.

The technological developments enable platform economies to rise and there is a major trend towards a sharing economy. People take advantage of the numerous offers of a sharing economy both in business to consumer (B2C) and consumer to consumer (C2C) approaches. Further collaborative platforms enable resources to be shared and utilised easily within the work environment as well as in private life. These digital platforms further support the DIY (do-it-yourself) society whereby self-production of fashion, technological equipment and food become the standard as consumers request tailor-made solutions. A DIY society with strong customer awareness obliges multinationals to use a "glocal" approach. Global companies hence compete with local players by recognizing differences in local taste and customs. Accordingly, companies have the flexibility to respond to local customer needs in order to remain on regional and local markets. At the same time, those global companies adapt their product and service offerings to a growing number of markets.

Disruptive technologies develop within this stable political and economic environment and additional solutions spread rapidly. These technologies not only increase the degree of freedom in manufacturing processes but also allow more efficient and effective work processes. Coupled with the ability to share and act upon the associated data and derived insights, new service- and production related business opportunities arise, especially for start-ups. While focusing on niche markets and lean organisational structures, they handle high volumes of data flow efficiently. Emerging technologies such as advancements in AI assist humans by undertaking planning and handling tasks autonomously. Since many physical and intellectual tasks are increasingly taken over by technical developments in automation and economic empowerment, this has the knock-on effect of a decrease in demand for manual labour. With the increasing exploitation of these technologies, the environment becomes highly automated and autonomous. The resulting knowledge-based economy's labour market is characterised by cross-disciplinary, creative profiles and lifelong learning. Employers cope with the demand for flexibility and will adopt an intercultural model partly equalising the resulting labour overflow.

These newly efficient work processes contribute to reducing the overall energy required within the industrial sector. In addition, technological developments allow for renewable energy generation as well as transmission and distributed energy resource systems to become more prevalent. Most importantly, politics actively enforces ecological development and ensures environmental regulations are updated

Table 2 Elements of the PrOCEEDIng scenario

Political concord in EU; widespread free trade; stable alliances
US and EU as global trade leaders; digital platform economics; Bank and Fintech collaboration; global companies operate locally
Social balance; adjusted labor market; strong consumption individualisation (DIY, variant diversity); living in smart cities
Digitalization and Industry 4.0 widely implemented; electrification and ecological transition far advanced; start-ups and SMEs push disruptive developments
Legislative keeps pace with technological development
Climate protection successful; resource wastage curbed

rapidly and early on. The PrOCEEDIng scenario contains the future projections mentioned in Table 2.

PrOCEEDIng—Effects on supply chain Global and multinational supply chains in the framework of this scenario have to adapt their supply chain structures towards a regionalised setting. Technological advancements and the legal frameworks allow for new, fast and responsive supply chains which are able to respond faster to changing customer needs. The advancements of digitisation allow for rapid recovery mechanisms in pandemic situations and enable a quick ramp up of supply chains, potentially with newly formed supply chain structures. Effects on structure and processes go hand in hand with requests for a circular economy and enforce circular product life cycle developments. From a process perspective, disruptive technologies support good and holistic planning via algorithms. The use of predictive analytics leads to better forecasts, improved efficiency and hence reduced or at least more predictive lead times. Therefore, the associated supply chain costs will decrease (e.g. through efficient risk management). Additionally, demand for highly individualised products involves flexible processes and equipment that are capable of handling a variety of products and material flows.

2.3 *"oFFsET"-Free Trade Enables Political and Social Development Whereas Fragmentation Hinders Technological and Environmental Change*

oFFsET—General settings

The scenario settings within oFFsET embrace diverse developments and can be characterised by the following aspects:

- Ecological problems and scarcity of resources are intensifying
- EU continues to develop steadily in political and economic terms
- Spread of technological innovations is thwarted, partly because of inadequate legislative frameworks

In this scenario, the world has to deal with severe environmental problems. CO_2 emissions are increasing around the world and there are major sources of greenhouse gas emissions. The most visible consequences include the continuous escalation of climate disasters and the increase in air, water and soil pollution. Climate change is combined with a severely ongoing depletion of resources for civil as well as industrial use; the ever-increasing global population and economic growth contribute detrimentally to the natural resources of our planet. Highly populated countries face severe issues related to water scarcity or complete lack of access to water. Climate change induces natural disasters and raises the frequency of pandemics, which in turn has a negative effect on the economy and reinforces social disparities. These environmental issues are reinforced by different factors from other future projections. A 'much and cheap' consumption attitude is adopted by consumers. Add to this the fact that the world is increasing the production of solid, hazardous and electronic waste. The recycling rate remains low and countermeasures to avoid high waste are implemented poorly, or, strong laws and policies for waste and recycling management are missing. The developments restrict any focus on environmental actions that support climate protection. Nevertheless, there are some ongoing countermeasures. They include, inter alia, the use of renewable energy resources and smart grid solutions that are promoted by better connectivity and efficiency in smart cities. At the same time, in the industrial sector, green systems are progressively applied for power generation, energy storage and transportation, such as hydrogen power cells and biomass. Standard mutual roadmaps and common policies are missing; for this reason, solutions for smart power grids develop more slowly than expected.

Political and economic uncertainties arise, which, inter alia, lead to ambiguous legislation, thus impeding the adoption of new services and important technological developments. It hinders the digital transformation of industries as the high cost of implementation, and reluctance towards new digital processes, slows down the redesign of processes. Only a few companies, mostly multinationals, overcome the legislative and regulatory constraints and implement the digital technologies that are available thus resulting in a coexistence of conventional and disruptive production technologies. Global players dominate while the big five IT companies (Google,

Table 3 Elements of the scenario oFFsET

Constant development in EU; free trade; instable alliances
Asia drives economic development; global companies act local; tech-giants dominate financial sector
Social balance; adjusted labor market; "much-and-cheap" consumption influenced by social media; living in smart cities
Digital transformation is slowing down due to cost and retention; autonomous systems are only occasionally successful; coexistence of conventional systems; further efforts for electrification and alternative energies
Legislation falls behind technological development; heterogeneous regulations and low levels of trust in data privacy and market regulation
Climate protection targets are not achieved; strong pollution; scarcity of resources

Apple, Facebook, Amazon, Microsoft) offer their own financing system to facilitate seamless payments. Table 3 outlines the integrated future projections of this scenario.

oFFSeT—Effects on supply chain

The depletion of resources disrupts business continuity, particularly for manufacturing companies that try to reuse their products and improve their designs in order to reduce material and disposal costs. Hence, sustainability and scarcity issues call for changes in several areas of the supply chain. Some companies may also relocate their plants to access resources or avoid barriers posed by regulations. Environmental regulations are not homogeneous and a common sustainability agreement throughout the supply chain is needed, such as is intended by the EU Circular Economy Action Plan (European Commission, 2020).

From a process perspective, a few new technological advancements allow some processes to be simplified so supply chains can work smoothly with reduced costs, thus serving the 'much-and-cheap' society. In addition, the 'much-and-cheap' consumption pattern requires lean and efficient process settings to reduce the overall logistics costs.

2.4 "DiThEr"—There Is Digital and Technological development but not Enough to compete Globally

DiThEr—General setting

The DiThEr scenario entails a mixed view on future developments and emphasizes technological innovations. This scenario is characterised by the following specifications:

- Continuous development and integration of new technologies, regardless of reluctance towards digitalisation
- Start-ups profit from technological developments
- Good acceptance of autonomous systems in the EU but this results in high unemployment and social imbalances
- Political environment changes towards protectionism
- Promotion of ecological and sustainable development of products.

In this scenario, the economic development in the EU benefits from the advances in technology, such as additive manufacturing, automation and the dynamic development of autonomous technology. These innovations make the production of individualised products with specific adjustments cost-effective, both for global players and SMEs. Companies try to postpone their production until the latest point possible to allow individual customisation, while the exploitation of disruptive production technologies promotes design-driven manufacturing processes and precise control in industry. These conditions promote the continuous exploitation of technologies and the fast development of autonomous technologies. Even though technology advances create new jobs, emerging skills are required and the re-employment of workers becomes difficult. In particular, robots and autonomisation take over manual and white-collar tasks: the unemployment rate increases and this contributes to social and political unrest. Pandemic outbreaks further enhance these developments and simultaneously trigger technological developments as well as business disruptions and social disparities.

Despite constant political development in the EU, across the globe, enclosed political environments lead to policies to protect domestic industries against foreign competition, entailing trade policies such as geographic barriers, tariffs, import quotas or other restrictions on imports from foreign competitors. These lead to complications in logistic structures, and some companies withdraw from the market. The EU is going into crisis and several countries are putting their own needs first and choosing to leave the union. This, though, in combination with the technology innovations, supports the establishment of DIY production. It particularly enables start-up companies to enter local market segments and introduce technological advancements. Such companies use new relations towards emerging economies, e.g. MINT countries (Mexico, Indonesia, Nigeria and Turkey). At the same time, stringent legal regulations, data management and privacy issues impede digital transformation. Digital transformation is advocated principally by multinationals who have the required financial resources to adopt the latest technological applications. Overall, the scenario

Table 4 Elements of the DiThEr scenario

Constant development in EU; closed economic areas; collapse of alliances
Asia drives economic development; global companies act local; digital platform economics; Bank and Fintech collaboration
Aging society with large disparities and high unemployment; strong consumer individualisation (DIY, variant diversity), living in smart cities
Digitalization obstructed by cost and retention; increased use of autonomous technologies; electrification and ecological systems are well advanced; start-ups benefit from the evolving technology industry
Legislation falls behind technological development; heterogenous regulations and low levels of trust in data privacy and market regulation
Climate protection successful; resource wastage contained by technological developments

states mixed developments with strong support from technological advancements. This also enables sustainable and ecological production technologies that support development and climate protection.

Table 4 describes the future projections within the scenario DiThEr.

DiThEr—Effects on supply chain

Future supply chains in this scenario need to be resilient due to an unstable environment and challenges derived from protectionism. Economic developments are difficult to predict, which makes it necessary to build strong local supply chains with regional partnerships. Nevertheless, personalised production and further partnerships with DIY entities require end-to-end tracking along the supply chain that encourages further aspects of transparency and circular economy. This therefore opens up ways for resource re-utilisation. Pandemic disruptions and natural disasters have strong effects on the operation of supply chains and induce the use of autonomous processes. Advancements in autonomous technologies lead to changes at process level with a focus on new ways to automate non-added value activities in the supply chain. Companies and politics need to consider that technological changes can cause unemployment; hence, strategies to reallocate staff along the supply chain need to be defined. This becomes even more important as disruptive changes create new production and service processes.

2.5 *"UNEaSE"—UNstable political sEtting and power Shifts hinder technological and Environmental development*

UNEaSE—General setting

UNEaSE provides a scenario with a mixed setting heading towards retrogressive development that includes the following main aspects:

- Growing political and economic uncertainty due to collapsing alliances, high unemployment and increasing social disparities
- Megacities and the economic focus on BRICS & MINT prohibit ecologically balanced development
- Outdated legislation as well as restricted digitalisation and limited technological developments cause traditional development of the economy.

The 'UNEasE' scenario comprises growing political and economic instability in the EU. The lack of stability helps BRICS and MINT countries to develop and become significant economic players with China playing a significant leading role. Besides, Chinese investments on economy and export markets further help China to overtake Europe as the world's net investor. Relations between countries become increasingly tough. Several trade relations suffer due to the political developments and lead to trade issues, which could potentially lead to trade wars. At the same time, increased protectionism as well as local and individualistic consumption patterns incentivise start-ups and SMEs. This, combined with the fact that society strives to promote DIY characteristics, enables small businesses to flourish. However, the rise of SMEs and start-ups leads to legal and political concerns due to the innate characteristic of dynamic markets created by the introduction of new business models. The political instability within the EU hinders legislative developments, however, and increases the development of heterogeneous regulations.

The focus on emerging countries leads to concern about legislation within increasingly dynamic markets, including a lack of heterogeneous environmental regulations, and low confidentiality of data and market participants. Lagging legislation also affects regulations and consumer protection laws in the EU. The lack of liability regulations in case of infringements mean core data and business secrets can be exposed. Challenges of data ownership and data management must be addressed in order to make use of the business potential inherent in digital transformation endeavours, which are often faced with lack of acceptance on the part of consumers, due to privacy or data security concerns. Only a few multinational companies are able to improve their performance through digital transformation, since only they can cope with the high costs and risks it involves.

The shift of economic dominance to emerging markets, combined with such heterogeneous regulations, sees economic priorities being placed before ecological ones, which in turn supports a steady increase in natural resources depletion. Highly populated countries face severe issues related to water and resource scarcity. A constant development towards megacities and the focus on emerging countries contribute to negative environmental impacts such as depletion of natural resources

Table 5 Elements of the UNEaSE scenario

Constant development in EU; protectionism; collapse of alliances
Asia, BRICS & MINT drive economic development; global companies act local; Bank and Fintech collaboration
Aging society with large disparities and high unemployment; strong consumer individualisation (DIY, variant diversity); living in smart cities
Digitalization obstructed by cost and retention; autonomous systems hardly prevail; further efforts for electrification and alternative energy sources; start-ups benefit from advancing technological development; coexistence of conventional and disruptive technologies
Legislation falls behind technological development; heterogeneous regulations and low levels of trust in data privacy
Climate protection targets are not achieved; strong pollution and scarcity of resources

and atmospheric pollution. These environmental developments support pandemic outbreaks and lead to political denunciations. This further promotes the trade issues mentioned above and increases the probability of trade wars. Table 5 describes the future projections inherent in the UNEaSE scenario.

UNEaSE—Effects on supply chain

In terms of supply chain structure and resources, the growing uncertainty and political instability in the EU as well as the shift of economic power to emerging markets leads companies to rethink their supply chains. Due to barriers to the free flow of goods, disruption to supply chains increase with longer waiting times at border crossings. As companies experience contracting markets and escalating logistics costs, they move to strategies such as right-shoring, which is the combination of on-shoring, near-shoring and far-shoring. Supplier location will play a crucial role in minimising costs, accessing resources and minimising environmental impacts. Firms that had identified low cost Asian suppliers experience a rise in labour costs, however, accessibility to resources such as rare earth elements makes these suppliers non-substitutable.

The slow adoption of new technologies impedes digital transformation. Thus, the traditional exchange of data dominates supply chain processes that restrain further network developments. For supply chains, SMEs and start-ups such as Fintech act as intermediaries in facilitating transactions and facilitate both the supplier and the contracting company to improve their working capital, which means greater liquidity in scheduling and disbursing payments.

2.6 *"ENDANGEr"-EuropeaN Disintegration and Protectionism lead to Geopolitical, Social, Environmental, Legal, Technological and Economic Issues that Affect Company's Success*

ENDANGEr—General setting

The ENDANGEr scenario displays a regressive future. Instability hinders future growth especially in terms of technological development. The following aspects summarize the features of this scenario:

Political instability and the collapse of the EU lead to the isolation of the former members

- Autonomous systems lead to high unemployment
- High social inequality and consumption of mass-market products
- Direct financial system with ledgering supports traditional goods exchange
- Little to no social development.

ENDANGEr describes an unstable political environment that causes social and economic issues. This incorporates a change in trade and hence a shift of gross domestic product from advanced economies towards emerging market economies. Political instability leads to stagnating and non-homogeneous legislation limiting the development of emerging technologies. Moreover, only a few big companies can take a leading role in managing and processing high volumes of data; thus, there are obstacles to achieving smooth digital transformation. In the financial sector, however, smart contracting with distributed ledgers enables customers' transactions to be carried out without any intermediary; hence, classic banking services are becoming obsolete. Instead, cryptocurrencies support the traditional exchange of goods.

Companies adapt their business structures with autonomous technologies and processes. In the EU, manual tasks are taken over by technical developments such as automatisation, which makes reemployment more difficult as it demands skilled workers. Since whole industries are affected by autonomisation, the overall rate of unemployment rises. Automated and partly autonomous factories are progressively becoming the standard in EU. This contributes to employees fearing for their jobs, eventually adopting a negative attitude towards emerging advanced technologies. Since complete industrial sectors are affected by automatisation, there is an increase in income disparities. Despite all efforts, high associated costs and unclear regulations hinder the proliferation of e-mobility, particularly in rural areas. Ambiguous regulations hinder common ecological agreements and as policy neglects environmental issues, pollution and the scarcity of resources increases. Table 6 states the different future projections, most of them regressive, for the scenario of ENDANGEr.

ENDANGEr—Effects on supply chain

The instability and stagnating development in this scenario affect supply chains in both their structures and processes as well as the supporting infrastructure that acts as an enabler for supply chains. Constrained public investment in logistic hubs,

Table 6 Elements of the ENDANGEr scenario

Political instability in EU; protectionism; collapse of alliances
Asia drives economic development; global companies act local; political instability leads to a traditional goods exchange based on crypto-currency
Strong social inequality especially; aging society with high unemployment forces to consumption of cheap mass-market products; living in smart cities
Digitalization obstructed by cost and retention; increased use of autonomous technologies; e-mobility and alternative energy sources benefit from previous research; dominance of multinationals inhibits further development of new technologies
Outdated, inhomogeneous legislation; low data privacy
No ecological agreements; heavy pollution; scarcity of resources

e.g. ports, means last mile and rural deliveries are frequently delayed. In addition, the fragmented market causes a shift towards local supply chains. This leads to raised costs due to the duplication of processes and inventories for each local supply chain. New local distributional and production hubs need to be set up and several new supplier partnerships have to be formed. The duplication of assets across the European region results in inefficiencies, and new barriers and taxes are expected. As the political and economic situation is instable, it affects the resilience of both global and local supply chains. Depending on how 'a world without banks' is set up, where financial processes are handled from individual to individual by means of an independent cryptocurrency, there might be an impact on payment processes.

The changes to supply chain processes lead to a rise in the complexity of managing processes and resources. The scenario settings here induce more bureaucracy and movements of goods become slower as handling steps are duplicated. Future economic developments require re-organisation as international supply chains face difficulties in maintaining relationships with suppliers. Accordingly, access to resources and commodities are affected and resource scarcity remains an issue. A fast development of autonomous systems provides a solution to efficient process design in distribution. As customers focus on cheap products, lean processes dominate as they can achieve corresponding cost reductions. New business models are required to handle the steering of autonomous systems and the increasing complexity within local markets. The setup of fragmented, local markets reduces possibilities for economies of scale and thus decreases efficiency. This is partly balanced out as economic and political developments create additional market barriers, which diminishes competition.

3 Conclusion

This chapter describes six macro-scenarios that provide settings for how future supply chains could be by 2030. The scenarios were developed by methodologically bundling relevant trends and experts then evaluated and discussed their content. Each macro-scenario contains an overview of the general scenario settings and then draws conclusions for its impact on supply chain structures and processes. Considering the generation of scenarios, it is of importance to highlight scenario descriptions as conceptual frameworks, which include progressive as well as stagnating or regressing views of the future. Accordingly, the interpretation of the impact on supply chains provides differentiated views of future developments. The scenario descriptions in this chapter enable companies to evaluate different scenario settings and to appraise the respective consequences. Companies, and their supply chain managers in particular, can use this to prepare themselves for upcoming strategic challenges.

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Scenario-Driven Supply Chain Charaterization Using a Multi-Dimensional Approach

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Abstract Extreme disruptive events, such as the volcano eruption in Iceland, the Japanese tsunami, and the COVID-19 pandemic, as well as constant changes in customers' needs and expectations, have forced supply chains to continuously adapt to new environments. Consequently, it is paramount to understand the supply chain characteristics for possible future scenarios, in order to know how to respond to threats and take advantage of the opportunities that the next years will bring. This chapter focuses on describing the characteristics of the supply chain in each of the six macro-scenarios presented in Sardesai et al. (2020b), as final stage of the scenario building methodology. Supply chains for each scenario are characterized in eight dimensions: Products and Services, Supply Chain Paradigm, Sourcing and Distribution, Technology Level, Supply Chain Configuration, Manufacturing Systems, Sales Channel, and Sustainability.

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1 Introduction

The late 1990s is often described as the time when the term supply chain management started to gain popularity. While the advent of globalisation increased competition and allowed for the search of new products, higher quality and lower cost, customisation brought new challenges to suppliers in order to fit the costumers' unique needs and expectations. Consequently, those years were characterised by massive changes in the way that companies interacted with each other and with customers (Min et al., 2019).

Since then, the ever-shifting global economy brings great challenges to companies and supply chains, as customers continually demand improvements in products and services and, at the same time, require lower prices, new sales channels, faster deliveries and social and environmental responsibility (Zimmermann et al., 2016). Looking into the future and trying to understand how to compare the possible scenarios and the corresponding innumerable challenges, as well as how to take advantage of the opportunities that the next years will certainly bring, are challenging tasks. These have to be faced by companies and governments in order to keep or increase competitiveness and to be able to create resilient and sustainable supply chain over time (Calatayud et al., 2019).

This chapter considers the macro-scenarios presented in Sardesai et al. (2020b) to discuss the fit of the supply chains, in terms of its overall characteristics. Thus, the research question driving this chapter is: *Which are the supply chain characteristics for the six macro-scenarios for Europe in 2030?*

This objective follows the scenario building method and describes the supply chains for each future macro-scenario based on the approach of the Consequence Matrix (Sardesai et al. 2020a). The idea is to provide insights into how the trends of each macro-scenarios can influence the behaviour of the companies and the supply chains. The results are a set of descriptions of the supply chains for the future macro-scenarios based on eight dimensions: Product and Service, Supply Chain Paradigm, Technology Level, Sourcing and Distribution, Supply Chain Configuration, Manufacturing Systems, Sales Channels and Sustainability.

2 Methodology

The research method followed to define the characteristics of the supply chains for the macro-scenarios for Europe 2030 is based on the consequence analysis of the scenario projections for various decision fields and is presented in Sardesai et al. (2020a). This consequence analysis is then represented in the "Consequence Matrix", which is the basis of the scenario transfer phase of Gausemeier et al. (1998) approach to scenario building (Sardesai et al. 2020a).

The decision fields for the Consequence Matrix were defined through literature review. As a first step, decision fields from the literature review were organized using the Product—Process—Supply Chain framework, also called three-dimensional concurrent engineering (Marsillac and Roh, 2014). Afterwards, the decision fields were re-organized into a final list of eight decision fields for the characterization of supply chains: Products and Services; Supply Chain Paradigm; Sourcing and Distribution; Technology Level; Supply Chain Configuration; Manufacturing Systems; Sales Channel; and Sustainability. Table 1 presents the list of the eight decision fields together with the alternatives for each of them.

Table 1 Decision fields for the consequence matrix

Decision field	Description	Alternative characteristics
Product and service (Fisher, 1997; Aitken, 2003; Godsell et al., 2011; Von Haartman, 2012)	Selection of the main type of products and services of the supply chains based on the demand characteristics of each macro-scenario.	**Mainstream Products**: standard, high volume markets **Customized Products**: personalized, high variety markets **Frugal Products**: low cost products with low maintenance and repair, while also providing robustness, user friendliness and economies of scale (Rosca et al., 2017) **Servitization:** transformation of products as stand-alone selling items towards package based customizable products with services attached (Vendrell-Herrero et al., 2017)
Supply chain paradigm (Lee, 2002; Wagner et al., 2012)	Selection of the supply chain paradigm based on the uncertainty level of demand and supply in each macro-scenario	**Efficient**: low uncertainty in demand and supply **Agile**: high uncertainty in demand and supply **Leagile**: high uncertainty in demand and low uncertainty in supply **Risk-hedging**: low uncertainty in demand and high uncertainty in supply
Sourcing and distribution (Christopher, 2016)	Selection of the widespread of sourcing and distribution in the supply chains for each macro-scenario	**Global**: sourcing/distribution is global **Local**: sourcing/distribution is local **Glocal**: mix between global and local sourcing/distribution
Technology level (Capgemini Consulting, 2013)	Selection of the digital mastery (i.e. technology-enabled initiatives regarding customer experience and internal operations) of supply chains in each macro-scenario	**Digital Masters**: strong adoption of digital technologies in the supply chain **Tech Fashionistas**: adoption of advanced digital technologies in segmented niches **Tech Beginners**: experimentation with technological adoption **Tech Conservatives**: strong presence of traditional technologies

(continued)

Table 1 (continued)

Decision field	Description	Alternative characteristics
Supply chain configuration (Gereffi and Lee, 2012)	Selection of the type of supply chain configuration for each macro-scenario, based on its governance, design and technology level	**Hyperconnected Factories**: integrated, network-based smart factories (Park, 2016) **Modular Systems**: decomposition of complex products and processes in modules that may be replicated in several supply chain echelons **Urban Manufacturing**: small-scale distributed production systems in cities (Kumar et al., 2016) **Simple Systems:** used for frugal mass products towards avoiding maintenance and repair (Rosca et al., 2017)
Manufacturing systems (da Silveira and Sousa, 2010)	Selection of the manufacturing strategy considering its fit with the demand characteristics and with the capabilities of supply chains in each macro-scenario	**Digital Lean Manufacturing**: Adding value by eliminating waste with a set of management practices and techniques supported by the implementation of digital technologies. Long-term relationship between manufacturer and supplier. (Arlbjorn and Freytag, 2013) **Digital Mass Customization**: Focused on broad provision of customized products and services by modularizing design, having flexible processes and allowing for integration (allowed by digital technologies) between supply chain members. Manufacturers provide affordable customization. (Fogliatto et al., 2012) **Agile Manufacturing**: Comprehensive response to business challenges of profiting from rapidly changing, continually fragmenting, global markets for high quality, high performance, customer configured goods and services. It is the ability to compete and prosper within a state of dynamic change. Aimed towards satisfying customers by configuring to order, it allows for unpredictability with strategies to face uncertainties. (Zhang and Sharifi, 2007) **Flexible Manufacturing**: Adaptation to customers preferences and changing need∀s. It must react with little penalty time, being either reactive (aimed at environmental uncertainty) or proactive (organization will redefine market uncertainties and influence customers desires). (Jain et al., 2013) **Efficient and Reconfigurable Manufacturing**: Classified in terms of the levels regarding decision-making and action-taking, where lower levels influence hardware changes and higher levels impact software changes or different choice of alternative methods/organization structures. It has the ability to reconfigure hardware and control resources at all functional and organizational levels, aimed at quickly adjusting production capacity and functionality as a response to sudden changes in market or in regulatory requirements. (Bi et al., 2008)

(continued)

Table 1 (continued)

Decision field	Description	Alternative characteristics
Sales channel (Beck and Rygl, 2015	Selection of the mechanism to sell products and services to customers in each macro-scenario	**Omnichannel:** integrated multichannel approach that delivers seamless customer experience across various online and offline channels (Hansen and Sia 2015) **Consumer to Consumer (C2C)**: consumers interact directly with each other to do business (Dan 2014) **Traditional Sales Channels**: products are sold through shops, stores and malls
Sustainability (Seuring and Müller, 2008)	Selection of the environmental and/or social focus of the supply chain in each macro-scenario	**Green supply chains**: focus on reducing environmental and ecological impacts (Batista et al., 2018) **Closed-loop supply chains**: focus on product returns (Guide and Van Wassenhove, 2006) **Resource-efficient supply chains**: focus on strategies to deal with resource scarcity (Matopoulos et al., 2015) **Social-responsible supply chains**: focus on social responsibility (Tang, 2018) **Humanitarian supply chains**: focus on coordination mechanisms in disaster relief (Balcik et al., 2010)

The Consequence Matrix is a table with the decision fields of Table 1 in the lines and the six macro-scenarios in the columns. The inputs to fill in the Consequence Matrix, i.e. to choose the alternative for each macro-scenario, came from three sources. First, the description of the macro-scenarios was used, which is summarized in Table 2. Second, a questionnaire was administered in 2018 and gathered the opinions of 62 experts from process industry, discrete manufacturing, distribution and logistics, ICT industry and academia. For each projection of Table 2, the following question was asked: “Please provide one or more outcomes/changes for your business and supply chain (e.g. SC structure or processes, business model, product portfolio, revenue, staff, IT) that will result from the projection”. Third, a workshop held with 15 experts from industry and 2 from academia at the SCM conference in Portugal in July 2018. During the expert workshops the six scenarios were presented as well as the correspondent product characteristics, and participants were asked to describe the implications of each scenario in the process and supply chain characteristics of their businesses.

The following section describes the supply chains characteristics for each macro-scenario and Table 9, in the conclusions section, presents the overview of the consequence matrix.

3 Supply Chains for Macro-Scenarios

This section presents the supply chain characteristics of each macro-scenario. Each table in the sub-sections is one column of the consequence matrix, plus the justifications provided by the experts for the alternative selected in each decision field. The

Table 2 Summary of macro-scenarios

Dimension	Descriptor	Projection	Code	Macro-scenarios: AsPRIRANT	PrOCEEDINg	OFFsET	DiThEr	UNEasE	ENDANGEr
Political	Political Setting	Political Concord in Europe	A1.1						
		Constant development in Europe	A1.2						
		Government collapse in Europe	A1.3						
	Trade Policies	Protectionism	A2.1						
		Free trade	A2.2						
	Confederation	Content Union	A3.1						
		Unstable Confederations	A3.2						
		Fragmentation	A3.3						
Economic	Global Trade Shift	The pendelum Shifts	B1.1						
		Steady Titans US & Europe	B1.2						
	Global Corporate Structures	Think global - act local	B2.1						
		Rise of born-global firms	B2.2						
	Digital Economy	Traditional economy persists	B3.1						
		Platform economy	B3.2						
		Pure traditional economy	B3.3						
	Financial Innovations	Bank and Fintech collaboration	B4.1						
		A world without banks	B4.2						
		Big 5 are the banks of future	B4.3						
Social	Demographic Change	Ageing population and acceleration of disparities	C1.1						
		Awareness of inequalities and wealth distribution	C1.2						
	Urban Living	Smart Regions	C2.1						
		Smart Cities	C2.2						
	Consumption Patterns	Much and Cheap	C3.1						
		Consumption awareness	C3.2						
		DIY Soceity	C3.3						
	Customer Orientation	Individualism - Focus on variety	C4.1						
		Collectivism - Focus on the crowd	C.4.2						
	Knowledge-based Economy	Investments equalise the labour market	C5.1						
		Rapid changes cause unemployment	C5.2						
Technological	Digital Transformation	Rapid advancement of digitisation and digitalisation	D1.1						
		Obstacles restrain digital transformation	D1.2						
	Autonomous Systems	Dynamic development of autonomous technologies	D2.1						
		Innate reluctance to accept autonomous technologies	D2.2						
	Alternative energy generation; storage and usage	Established Electrification Technologies and Green Systems	D3.1						
		Ongoing electrification and alternative energy endeavours	D3.2						
	Decentralised connection of information and physical devices	Dominance of Global Players	D4.1						
		Start-ups and SMEs take up business	D4.2						
	Disruptive Production Technologies	Continuous exploitation of disruptive technologies	D5.1						
		Coexistence of conventional and disruptive technologies	D5.2						
Legal	Consumer Protection Laws	Promotion of laws and full product transparency	E1.1						
		Legislation is lagging behind dynamic market development	E1.2						
	Intellectual Property Laws	Full security for inventors and data providers	E2.1						
		Low confidentiality for data and market participants	E2.2						
	Social and Environmental Regulations	Comprehensive regulatory framework	E3.1						
		Heterogeneous regulations	E3.2						
Environ-mental	Climate Change	Our planet is recovering	F1.1						
		Our planet is on the brink	F1.2						
	Environmental Resource Management	Countering resource depletion	F2.1						
		Rise in depletion of natural resources	F2.2						

brackets in the tables include the projections of Table 2 that support the supply chain characteristic of each macro-scenario. The full description of the macro-scenarios is available in Sardesai et al. (2020b).

3.1 Supply Chain for Macro-Scenario "aSPIRANT"

In aSPIRANT macro-scenario, economic climate is shaped by the multiplicity and competitive capabilities of born-global firms and platform businesses. According to this scenario, Europe and neighboring regions do not face political upheavals, calamities, or any other political risk factors that affect the demand predictability and interrupt the flow of commerce. Therefore, the product portfolio will be mainly standardized, i.e. supply chains are dominated by mainstream products. Consensual and market-preserving political settings, consolidated by state unions, bring both economic flexibility and market certainty in bargaining process; whereas, soft regulations facilitate liberal trade security, easy access to raw materials and investment finance. In this sense, the predominant supply chain paradigm is "Efficient", characterized by low supply and demand uncertainty (Lee, 2002; Wagner et al., 2012).

The aSPIRANT scenario is linked to high-tech manufacturing, where servitisation strategy plays an important role in designing the business/operating model of manufacturing processes, which are based on the digital. Technology level in aSPIRANT is increased by: (1) high investments on technology and related processes, (2) training, and R&D; (3) development of new digital technologies and cybersecurity systems; (4) automation of non-value-added activities; and (5) development of technical skills and specialized IT staff. New digital business, data-driven and real- and near-time tracking/traceability technologies contribute to the development of omnichannel sales, demand pooling (leading to raw materials cost savings) and new revenue streams. Thus, this scenario is predominately characterized by global sourcing and distribution and by hyperconnected factories in terms of supply chain configuration. Furthermore, in a scenario with low variety, low supply uncertainty, large production facilities and digital technologies adoption, digital lean manufacturing is the most suitable manufacturing system.

Finally, in terms of sustainability, this scenario is characterized by environmental and social awareness and companies are prone to adopt green and socially responsible closed-loop supply chain strategies. Table 3 presents the summary of the supply chain characteristics for aSPIRANT scenario.

3.2 Supply Chain for Macro-Scenario "PrOCEEDINg"

The "PrOCEEDINg" macro-scenario is a positive scenario in the sense that most of the trends change in such a way that they help companies with the implementation of innovative SC models, where political and legal situations are stable and new market opportunities are arising from social conditions. This scenario, characterised by political stability and combined with free trade between contended unions, opens up possibilities for wide customisation opportunities. The continuity of power dominance of Europe and the U.S.A., coupled with digital transformations and collaborations between traditional financial establishments and FinTech companies, encourages rapid advancement of digitalisation processes, as well as dynamic development of autonomous technologies. These features, combined with the expected global sourcing and distribution, lead to hyperconnected factories as supply chain configuration. In PrOCEEDINg, start-ups and SMEs will take up business, while global competitors must adapt products to local culture, especially with the advent of a DIY focused society strongly supported by individualism. In this sense, customized product portfolios, servitization, as well as omnichannel and C2C sales channel, as well as digital mass customization as manufacturing systems, are required to succeed on this scenario. This increase in customization leads to an environment characterized by high degrees of demand uncertainty, although with relatively low levels of supply uncertainty—due to the easier access to materials and components, many supply sources and predictable lead-times—requiring companies to adopt strategies that combine characteristics of a lean and agile supply chain strategies, usually know as a leagile strategy (Zimmermann et al., 2020).

With an economy being digitalised in nature and based on growing digital potential, technologies based on the digitalisation concept thrive and receive more R&D investments. However, high automation on developed countries and low automation

Table 3 Supply chain characterization for macro scenario "aSPIRANT"

Decision field	SC characteristics for "aSPIRANT"	Explanation
Product and service	Mainstream products and Servitisation	• Market expansion: geographical (A1.1, A2.2), economic growth in US & Europe (B1.2), new customers from digital business (B1.2, B3.2) • More global competitors (A2.2, A3.1, B2.2, C4.2, D4.1): Small and start-up companies are 'born global' (B2.2), Less differentiation, thus more competition (C4.2) • Low variety influenced by: Products for new markets (geographical expansion A1.1, A2.2), Collectivism (C4.2), Consumption awareness (C3.2) • Product portfolio: Standardization (B1.2), More green products (C3.2, F1.1), More data-driven services (B3.2, D5.1)
Supply chain paradigm	Efficient	• Stable demand, due to low variety and standardization (see above) • Stable supply, due to easier access to specific materials and components (A2.2, C2.1, F2.1), many supply sources (A2.2, F2.1), and predictable lead-times (A1.1, A2.2, B1.2, B3.2, D1.1, D2.1)
Sourcing and distribution	Global sourcing Global distribution	• Global sourcing (A2.2, B2.2, D4.1) • Global distribution (A2.2, A3.1, B2.2, D4.1)

(continued)

Table 3 (continued)

Decision field	SC characteristics for "aSPIRANT"	Explanation
Technology level	Digital masters	• High investments (A1.1) on: technology (A2.2, B1.2, D5.1), processes, training (D5.1), and R&D (D1.1) • Digital technologies (B1.2, B3.2) • Automation of non-value-added activities (B1.2, D2.1): high automation in high labour cost country and manual process in low cost country (C5.1), cybersecurity systems (B4.3, E1.1, E2.1), robotic process automation (D1.1, D2.1), electric and hybrid vehicle systems (D3.1) • Technical skills and specialized IT staff required (C2.1, D1.1, D5.1), increased rate of labour force growth (C1.2), increased investment on staff (B1.2), higher skill availability (C5.1)
Supply chain configuration	Hyperconnected factories	• Steady titans US & Europe (B1.2) assure capability for European and US companies to drive global SC. • Global sourcing and distribution enable to digital masters (see above)
Manufacturing systems	Digital lean manufacturing	Low variety, low supply uncertainty, large production facilities, digital technologies adoption (see above)
Sales channel	Omnichannel	Digital transformation (B3.2, D1.1, D5.1) Consumption awareness (C3.2)
Sustainability	Green Social responsible Closed-loop	Green: Environmental awareness (F1.1, F2.1) Social-responsible: Awareness of inequalities and wealth distribution (C1.2) Closed-loop: Digital transformation (B3.2) and environmental awareness (E3.1, F1.1, F2.1)

on underdeveloped countries are expected results, especially when considering the power dominance of the steady titans. The rise of circular economy exposes the need for a closed-loop supply chain, which concerns the circularity in supply chain configurations with restorative and regenerative processes (Batista et al. 2018). This archetype can be integrated with the green supply chain, which relates to scenarios where the decision-making is made based on environmental concerns without much focus on the financial performance (Laari et al., 2016; Melnyk et al., 2010; Salmani et al., 2018). Table 4 presents the summary of the supply chain characteristics for PrOCEEDINg scenario.

Table 4 Supply chain characterization for macro scenario "PrOCEEDINg"

Decision field	SC characteristics for "PrOCEEDINg"	Explanation
Product and service	Customized products and servitization	• Market expansion: geographical (A1.1, A2.2), economic growth in US & Europe (B1.2), new customers from digital business (B1.2, B3.2) • Decreased market size and demand of many products due to Do-It-Yourself (DIY) society (C3.3) • More global competitors (A2.2, A3.1); Global competitors adapt their product to the local culture (B2.1); Reduced competition due to needed investments on sustainability (F1.1), • High variety influenced by: products for new markets (geographical expansion A1.1, A2.2), individualism (C4.1), product differentiation for global companies present in local markets (B2.1) • Product portfolio: standardization (B1.2), customization (B3.2, C3.3, C4.1), more green products (F1.1), more data-driven services (B3.2, D5.1), DIY-products (C3.3)
Supply chain paradigm	Leagile	• Unstable demand due to high variety and customization (see above) • Stable supply due to easier access to specific materials and components (A2.2, F2.1), many supply sources (A2.2, F2.1), and predictable lead-times (A1.1, A2.2, B1.2, B3.2, D1.1, D2.1)
Sourcing and distribution	Global sourcing Global distribution	• Global sourcing (A2.2) • Global distribution (A2.2, A3.1)
Technology level	Digital Masters	• High investments on (A1.1): technology (A2.2, B1.2, D5.1), processes, training (D5.1), R&D (D1.1) and education (lifelong learning) • Digital technologies (B1.2, B3.2): Cloud-based software platforms (D2.1); IoT (D2.1); Data Science (D2.1); Communications Infrastructure (D2.1); Cybersecurity systems (E1.1, E2.1) • Automation of non-value-added activities (B1.2, D2.1): high automation in high labour cost country and manual process in low cost country (C5.1); robotic process automation (B1.2, D1.1, D2.1); automated transportation (B1.2, D2.1); self-driving vehicles (D2.1), additive manufacturing of critical parts (D2.1); • Environmentally friendly technologies: Renewable energy technologies; New electrification systems electric and hybrid vehicle systems (D3.1) • Technical skills and specialized IT staff required (D1.1, D5.1), increased rate of labour force growth (C1.2), increased investment on staff (B1.2)

(continued)

Table 4 (continued)

Decision field	SC characteristics for "PrOCEEDINg"	Explanation
Supply chain configuration	Hyperconnected factories	• Steady titans US and Europe (B1.2) assure capability for European and US companies to drive global SC • Global sourcing and distribution and digital masters (see above)
Manufacturing systems	Digital mass customization	High variety, low supply uncertainty, small and medium production facilities (D4.2), digital technologies adoption (see above)
Sales channel	Omnichannel C2C	Digital transformation (B3.2, D1.1, D5.1) Do-it-yourself society (C3.3)
Sustainability	Green Social-responsible Closed-loop	Green: Environmental awareness (E3.1, F1.1, F2.1) Social-responsible: Awareness of inequalities and wealth distribution (C1.2) Closed-loop: Digital transformation (B3.2) and environmental awareness (E3.1, F1.1, F2.1)

3.3 Supply Chain for Macro-Scenario "OFFsET"

The macro-scenario "oFFsET" can be described in general as a moderated scenario. It is characterised by a partially positive political environment due to open borders and reduced import and export tariffs, which enable the conditions for an agile global sourcing and distribution. From the demand point of view, oFFsET scenario is driven by a moderate market expansion mainly due to a constant development of policies in Europe in a free trade setting, where emerging economies, principally from Asia, open new markets. Due to a moderate market expansion and more global competitors (although with some level of adaption of the products to the local culture) this scenario is characterized by less differentiation, more competition and smaller customer portfolio, leading to the predominance of mainstream products. Due to free trade and an increasing political unrest in countries neighboring Europe, companies need to think glocal in terms of supply and distribution. Additionally, as a result of the low demand uncertainty (due to low variety) and high supply uncertainty (due to resource scarcity), a risk-hedging SC strategy is expected to be predominant, as well modular systems and agile manufacturing systems, with large production facilities.

The existence of ambiguous regulation affects both technology and environment decisions. From the technological point of view, the lack of regulations has a direct impact on digital transformation, impeding a sustained development; only occasionally some technologies are successfully implemented by global companies, which can afford its adoption. In this sense, traditional sales channels are predominant. Ambiguous regulations for the environment, which do not face climate change challenges, combined with increasing global population (mainly living in cities fostering the expansion of urban areas), and thus growing consumerism, are exhausting natural resources. Thus, a resource-efficient social-responsible paradigm tends to be predominant. Table 5 presents the summary of the supply chain characteristics for oFFsET scenario.

Table 5 Supply chain characterization for macro scenario "oFFsET"

Decision field	SC characteristics for "oFFsET"	Explanation
Product and service	Mainstream products	• Moderate market expansion: geographical (A1.2, A2.2), new markets in emerging economies (B1.1) • More global competitors (A2.2, C4.2, D4.1): Global competitors adapt their product to the local culture (B2.1), i.e. less differentiation, thus more competition (C4.2), and smaller customer portfolio due to challenges in IP protection (E2.2); Disaggregation of SC (D1.2), i.e. big multinational with advanced IT (D1.2) and small companies will lose IT pace (D1.2) • Low variety influenced by: products in emerging economies (B1.1), collectivism (C4.2), product differentiation for global companies present in local markets (B2.1, D3.2) • Product portfolio: duplication of product portfolios across regions (A1.2), sustainable products for conscious consumers (E3.2)
Supply chain paradigm	Risk-hedging	• Stable demand due to low variety (see above) • Unstable supply due to resource scarcity (F1.2, F2.2)
Sourcing and distribution	Glocal sourcing Glocal distribution	• Glocal sourcing (A2.2, B2.1, D4.1, F1.2, F2.2) • Glocal distribution (A2.2, A3.2, B2.1)
Technology level	Tech conservatives	• Local technological investment (A3.2, B2.1) • Cybersecurity constraints (B3.3, B4.3, D1.2, E2.2) • Automation of non-value-added activities: high automation in high labour cost country and manual process in low cost country (C5.1, D4.2) • Hydrogen power cells and biomass (D3.2) • Lack of specialized staff (D1.2) and increased rate of labour force growth (C1.2)
Supply chain configuration	Modular systems	• Pendulum shifts (B1.1) and much and cheap (C3.1) • Mainstream products and tech conservatives (see above)
Manufacturing systems	Agile manufacturing	Low variety, high supply uncertainty, large production facilities (see above)
Sales channel	Traditional sales channels	Digital impediment (B3.3) Obstacles restrain digital transformation (D1.2)
Sustainability	Resource-efficient Social-responsible	Resource-efficient: resource scarcity (F1.2, F2.2) Social-responsible: Awareness of inequalities and wealth distribution (C1.2)

3.4 Supply Chain for Macro-Scenario "DiThER"

The macro-scenario "DiThER" is a mainly positive scenario as there is an increasing influence of digital transformation, development of autonomous technologies, establishment of electrification technologies and green systems, the continuous exploitation of disruptive technologies and investment in smart cities. Regarding the demand characteristics, the supply chain scenario is based on market contraction, due to protectionism and fragmentation, customization, given that this society is supported on the DIY concept of consumerism, and new markets in emerging countries. Due to the market contraction there will be reduced competition and global competitors will adapt their product to the local culture. Thus, customized products and servitization are required, and, considering the product variety caused by individualism and uncertain demand, there will be a high complexity and mainly small and medium production facilities with flexible manufacturing systems.

Due to protectionism and heterogeneous regulations, there will be moderate supply sources causing uncertain lead-times and a higher suppliers' risk. An agile supply chain is thus expected to fit with the high demand and supply uncertainty. Regarding the distribution characteristics, the focus will be on local distribution due to protectionism and fragmentation on the political level and C2C will be paramount as sales channel because of individualism, DIY society and digital transformation.

When it comes to the technologies, the focus, especially in the smart cities, will be on environmentally friendly self-driving vehicles, robots and autonomous transport systems. Applications of IoT, data science and communication infrastructure will be widespread, enabling urban manufacturing, mainly due to the dynamic development of autonomous technologies. The environmental awareness will demand green closed-loop supply chain and new environmentally friendly materials will arise given the focus on individualism and DIY. Table 6 presents the summary of the supply chain characteristics for DiThER scenario.

3.5 Supply Chain for Macro-Scenario "UNEasE"

The scenario "UNEasE" describes an unstable political environment in which companies have to face protectionism, economic uncertainty and alliance collapse. This scenario is also characterised by poor legislations in different fields: from the heterogeneous environmental regulations, which cause a continuous resource depletion, to the laws to protect intellectual property and customer data, which are lagging behind significantly. This creates obstacles for a complete digital transformation of society and companies act mainly in the business to business environment. The traditional economy persists, coexisting with disruptive practices, often used by big players. SMEs and start-ups compete in the local markets where they are able to create a large variety of products to answer to customer individual needs, arising from the DIY trends.

"UNEasE" presents supply chains with customized products, leagile supply chain paradigm, glocal sourcing and local distribution strategies. Moreover, these supply chains are low-tech (tech conservatives) and the supply chain configuration is based on urban manufacturing strategy, aided by flexible manufacturing and traditional sales channels. Customization will become a pivotal instrument to meet customer needs above the barriers created by protectionism and cultural differences, and this will demand more flexibility in the supply chain logistics for delivering the required product mix. Hence, the variety of the demand will spread, and companies will

Table 6 Supply chain characterization for macro scenario "DiThER"

Decision field	SC characteristics for "DiThER"	Explantion
Product and service	Customized products and servitization	• Market contraction (A1.2, A2.1, A3.3): new markets in emerging economies (B1.1), decreased market size and demand of many products due to DIY society (C3.3) • Reduced competition (A1.2, A2.1); Global competitors adapt their product to the local culture (B2.1), i.e. smaller customer portfolio due to challenges in IP protection (E2.2); Disaggregation of SC (D1.2), i.e. big multinational with advanced IT (D1.2) and small companies will lose IT pace (D1.2) • High variety influenced by: products in emerging economies (B1.1), individualism (C4.1), product differentiation for global companies present in local markets (B2.1) • Product portfolio: overlapping product development activities and portfolios across regions (A1.2), more data-driven services (B3.2, D5.1), DIY-products (C3.3), customization (B3.2, C3.3, C4.1), sustainable products for conscious consumers (E3.2), more green products (F1.1)
Supply chain paradigm	Agile	• Unstable demand due high variety and customization (see above) • Unstable supply due to access to protectionism (A2.1) and heterogeneous regulations (E3.2)
Sourcing and distribution	Local sourcing Glocal distribution	• Local sourcing (A2.1, B2.1) • Glocal distribution (A2.1, B2.1, B3.2)
Technology level	Tech fashionistas	• Investment on: technology (D5.1, F1.1, F2.1) and training (D5.1) • Digital technologies (B3.2): Cybersecurity -constraints (D1.2, E2.2), IoT (D2.1), Data Science (D2.1), Communications Infrastructure (D2.1) • Automation of non-value added activities (D2.1): Autonomous systems (aging population), Robotics, Automated transportation, Self-driving vehicles • Additive Manufacturing of critical parts (D2.1) • Electric and hybrid vehicle systems (D3.1) • Environmentally friendly technologies • Multi-disciplinary staff (technology, market, languages, digital/analytical skills), leadership skills (D5.1), high unemployment rates (C1.1, C2.2, C5.2)
Supply chain configuration	Urban manufacturing	Smart cities (C2.2), think global-act local (B2.1), focus on variety, DIY society (C3.3)

(continued)

Table 6 (continued)

Decision field	SC characteristics for "DiThER"	Explantion
Manufacturing systems	Flexible manufacturing	High variety, small and medium production facilities, autonomous technologies adoption (see above)
Sales channel	C2C (consumer2consumer)	Do-it-yourself society (C3.3) Legislation hinders digital transformation (E1.2, E2.2, E3.2)
Sustainability	Green Closed-loop	Green: Environmental awareness (F1.1, F2.1) Closed-loop: Digital transformation (B3.2) and environmental awareness (F1.1, F2.1)

be asked to manage wider product portfolios. From the supply perspective, supply chains will be required to comply with lower costs of sourcing and inbound logistic.

Low levels of new technology adoption and the prevalence of small and medium production facilities in the different manufacturing sectors affect production efficiency, and request additional efforts to minimize resource consumption, in particular concerning water, and carbon emission. This kind of SC features allows to face lockdown similar to the one caused by recent COVID-19 assuring the provision of materials and products at local level. Regarding environmental and social strategies, resource-efficient and humanitarian SC strategies are employed with the aim to quickly react to possible disastrous environments. Table 7 presents the summary of the supply chain characteristics for UNEasE scenario.

3.6 Supply Chain for Macro-Scenario "ENDANGEr"

The "ENDANGEr" macro-scenario can be considered as a pessimistic scenario since companies are facing an unstable political environment in Europe, a 'global trade shift' from advanced economies towards emerging market economies, as well as protectionism. Moreover, climate change, sanitary crisis, resource scarcity, and the lack of environmental and digital regulations are putting companies to high risks and challenges.

In the "ENDANGEr" scenario, the rise of new business models and digital innovation, the continuous efforts to reduce products' prices, and the resource scarcity lead to the development of frugal mass products. In fact, companies use frugal mass products to respond to the lack of necessary resources and/or infrastructure and meet their customers' needs in constrained environments (Mourtzis et al., 2016). One the one hand, markets are composed of different segments that have their own distinct needs and preferences, and companies respond to local needs which are strongly influenced by social networks, leading to relatively low demand uncertainty. On the other hand, supply chains face protectionism (e.g. tariffs on imported goods and

Table 7 Supply chain characterization for macro scenario "UNEasE"

Decision field	SC characteristics for "UNEasE"	Explanation
Product and service	Customized products	• Market contraction (A1.2, A2.1, A3.3): new markets in emerging economies (B1.1), decreased market size and demand of many products due to DIY society (C3.3) • Reduced competition (A1.2, A2.1); Global competitors adapt their product to the local culture (B2.1), i.e. smaller customer portfolio due to challenges in IP protection (E2.2); Disaggregation of SC (D1.2), i.e. big multinational with advanced IT (D1.2) and small companies will lose IT pace (D1.2) • High variety influenced by: 1) products in emerging economies (B1.1), 2) individualism (C4.1), and 3)product differentiation for global companies present in local markets (B2.1, D3.2) • Product portfolio: duplication of product portfolios across regions (A1.2), customization (C3.3, C4.1), sustainable products for conscious consumers (E3.2), DIY-products (C3.3)
Supply chain paradigm	Agile	• Unstable demand due high variety and customization (see above) • Unstable supply due to resource scarcity (F1.2, F2.2)
Sourcing and distribution	Glocal sourcing Local distribution	• Glocal sourcing (A2.1, B2.1, B3.1, D4.1, F1.2, F2.2) • Local distribution (A2.1, B2.1, B3.1)
Technology level	Tech conservatives	• Low investment leading to less innovation in products and processes (A2.1) • Low level of automation (D2.2) • Cybersecurity constraints (D1.2, E2.2) • Rise of sharing economy (B4.1) • Hydrogen power cells and biomass (D3.2) • Lack of IT Specialized staff (C5.2, D1.2), high unemployment rates (C1.1, C2.2, C5.2)
Supply chain configuration	Urban manufacturing	Smart cities (C2.2), think global-act local (B2.1, D4.2), focus on variety, DIY society (C3.3)
Manufacturing systems	Flexible manufacturing	High variety, small and medium production facilities, autonomous technologies adoption (see above)
Sales channel	Traditional sales channels	Traditional economy persists (B3.1) Obstacles restrain digital transformation (D1.2)
Sustainability	Resource-efficient Humanitarian	Resource-efficient: resource scarcity (F1.2, F2.2) Humanitarian: increased climate change consequences (F1.2)

import quotas) or lockdowns at global level caused by pandemic diffusion, generating high supply uncertainty and requiring the adoption of risk-hedging supply chain strategies. In terms of manufacturing systems, efficiency and reconfigurability would help companies to face the above-mentioned characteristics.

As protectionism policy restricts the international trade and companies will face barriers and several tariffs, local supply chains will be developed. That means that upstream in the supply chain, companies will source glocally by forming new partnerships and downstream in the supply chain, companies will sell their products locally. Regarding the technological dimension, the political and social instability limits the development of emerging technologies. Due to high costs and risks, the digitalisation is only afforded by big companies. However, that gives the chance to SMEs to develop autonomous technologies and become tech-beginners to face the need to have self-standing production and assure remote working conditions.

In terms of sustainability, companies will be forced to become resource-efficient due to the depletion of resources and they will learn to use the resources in a sustainable manner. The impacts of climate change provoke extreme events and therefore humanitarian supply chains will be prepared to quickly respond to these catastrophes. Table 8 presents the summary of the supply chain characteristics for ENDANGEr scenario.

Table 8 Supply chain characterization for macro scenario "ENDANGEr"

Decision field	SC characteristics for "ENDANGEr"	Explanation
Product and service	Frugal products	• Market fragmentation (A1.3, A2.1, A3.3) and new markets in emerging economies (B1.1) • Reduced competition (A1.3, A2.1); Global competitors adapt their product to the local culture (B2.1, D4.1), i.e. less differentiation, thus more competition (C4.2); Smaller customer portfolio due to challenges in IP protection (E2.2); Disaggregation of SC (D1.2), i.e. big multinational with advanced IT (D1.2) and small companies will lose IT pace (D1.2) • Low variety influenced by: products in emerging economies (B1.1), collectivism (C4.2), and product differentiation for global companies present in local markets (B2.1, D3.2, D4.1) Product Portfolio: Duplication of product portfolios across regions (A1.3), sustainable products for conscious consumers (E3.2), mass-market products
Supply chain paradigm	Risk-hedging	• Stable demand due to low variety (see above) • Unstable supply due to resource scarcity (F1.2, F2.2)

(continued)

Table 8 (continued)

Decision field	SC characteristics for "ENDANGEr"	Explanation
Sourcing and distribution	Glocal sourcing Local distribution	• Glocal sourcing (A2.1, B2.1, B3.1, D4.1, F1.2, F2.2) • Local distribution (A2.1, B2.1, B3.1)
Technology level	Tech beginners	• Low investment leading to less innovation in products and processes (A1.3, A2.1) Automation of non-value-added activities (D2.1): Autonomous systems, automated transportation, self-driving vehicles (D2.1) • Cybersecurity constraints (D1.2, E2.2) • Hydrogen power cells and biomass (D3.2) • Lack of IT Specialized staff (C5.2, D1.2), high unemployment rates (C1.1, C2.2, C5.2)
Supply chain configuration	Simple systems	• Pendulum shifts (B1.1) and much and cheap (C3.1) • Frugal mass products and tech beginners (see above)
Manufacturing systems	Efficient and reconfigurable manufacturing	Low variety, high supply uncertainty, large production facilities, autonomous technologies adoption (see above)
Sales channel	Traditional sales channels	Traditional economy persists (B3.1) Obstacles restrain digital transformation (D1.2)
Sustainability	Resource-efficient Humanitarian	Resource-efficient: resource scarcity (F1.2, F2.2) Humanitarian: political instability (A1.3) and increased climate change consequences (F1.2)

4 Conclusions

This chapter described six future supply chains scenarios based on eight strategic dimensions: Product and Service, Supply Chain Paradigm, Technology Level, Sourcing and Distribution, Supply Chain Configuration, Manufacturing Systems, Sales Channels, and Sustainability. Table 9 shows the overview of the supply chains' characterization for each macro-scenario.

The characteristics of the supply chains for each macro-scenario were derived from the macro-scenario projections, complemented by the opinions of experts. The results of this chapter provide the basis for defining the technologies that are needed in each of the future scenarios (Senna et al., 2020), which will then lead to the analysis of Research Priorities and Public Policy Recommendations for the future supply chains in Europe 2030 (Fornasiero et al., 2020).

In this work, a proposal of the supply chain characteristics or features is presented as a support for companies to understand how to link their way of working to the external conditions (political, economic, social, technological, legal and environmental), towards reacting and adapting to them. Given this, it is important to discuss some managerial implications for the definition of a path to innovation starting from the awareness that external and internal conditions are interlinked in the definition of this path.

In particular, macro-scenarios with positive features (such as aSPIRANT and PrOCEEDINg) are characterized by a favourable environment for the technological development and creation of appropriate eco-systems for cross-fertilisation among companies and different sectors. Moreover, in this kind of macro-scenarios, SCs have the right capabilities to respond efficiently to the external environment: companies fully master digitalisation and SCs are hyper-connected, integrated with upstream and downstream and inclusive to valorise humans; in this kind of scenarios it is expected that the research can be easily stimulated with the aim of consolidating the strategies and practices already implemented by networks and springing companies to even higher and better performance as well as doing further important steps to explore highly cutting-edge solutions. Also, implementation of sustainability strategies towards circular economy will be facilitated by the legislation and political conditions.

For the other scenarios, where the external conditions can have negative impact on SC, such as social changes (i.e. increasing aging society bringing difficulties to find young workers), economic restrictions (i.e. protectionism, and large companies monopolies bringing difficulties to find global suppliers and global markets) and legal obstacles (i.e. heterogeneous legislation and lack of consumers' data protection), SCs innovation advancement is limited by all these impediments. Consequently, the full implementation of adequate SC research policies should be accompanied by actions such as training, creation of adequate infrastructures, definition of adequate finance tools, that will help to increase the readiness to invest in research projects in order to pass from being digital beginner or tech conservative to digital masters. In this case, it is necessary to propose innovation paths to help the supply chains and the companies to increase the technological level of the networks by creating tools and models to face efficiently the challenges and issues of each specific scenario (see Fornasiero et al., 2020).

Table 9 Supply chain characterization for macro-scenarios

Decision field	Macro-scenario "aSPIRANT"	Macro-scenario "PrOCEEDINg"	Macro-scenario "oFFsET"	Macro-scenario "DiThER"	Macro-scenario "UNEasE"	Macro-scenario "ENDANGEr"
Product and service	Mainstream products and servitisation	Customised products and servitisation	Mainstream products	Customised products and servitisation	Customised products	Frugal products
Supply chain paradigm	Efficient	Leagile	Risk-hedging	Agile	Agile	Risk-hedging
Technology level	Digital masters	Digital masters	Tech conservatives	Tech fashionistas	Tech conservatives	Tech beginners
Sourcing and distribution	Global sourcing Global distribution	Global sourcing Global distribution	Glocal sourcing Glocal distribution	Local sourcing Glocal distribution	Glocal sourcing Local distribution	Glocal sourcing Local distribution
Supply chain configuration	Hyperconnected factories	Hyperconnected factories	Modular systems	Urban manufacturing	Urban manufacturing	Simple systems
Manufacturing systems	Digital lean manufacturing	Digital mass customisation	Agile manufacturing	Flexible manufacturing	Flexible manufacturing	Efficient and reconfigurable manufacturing
Sales channel	Omnichannel	Omnichannel C2C	Traditional sales channels	C2C	Traditional sales channels	Traditional sales channels
Sustainability	Green Social responsible closed-loop	Green Social responsible closed-loop	Resource-efficient Social responsible	Green Closed-loop	Resource efficient Humanitarian SC	Resource efficient Humanitarian SC

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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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Enabling Technologies for Future Supply Chains

Technology Scouting to Accelerate Innovation in Supply Chain

Markus Stute, Saskia Sardesai, Matthias Parlings, Pedro Pinho Senna, Rosanna Fornasiero, and Sébastien Balech

Abstract Digital technologies have gained ground among companies, researchers and policy makers in recent years due to their growing relevance to current and future supply chains. Technologies such as robotics, artificial intelligence, autonomous transport systems, data science, and additive manufacturing are gradually becoming part of people's and companies' daily lives and are changing the manufacturing, process industry and logistics sectors. Although recent attempts have been made to understand the implications of these technologies on supply chain management, the relevance of the different technologies in future scenarios is still unknown. Using a technology scouting approach, the most important enabling technologies for supply chains until 2030 are identified and selected and their implications on future supply chains are evaluated using an assessment methodology with different evaluation criteria.

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1 Introduction to Enabling Technologies and Technology Scouting

Enabling technologies can be characterised as widely applicable technologies resulting from advanced scientific and engineering activities that enable the creation of new or the improvement of existing products and services (Commission of the European Communities 2009; Teece 2018). The European Commission describes key enabling technologies as knowledge intensive, multidisciplinary and "associated with high R&D intensity, rapid innovation cycles, high capital expenditure and highly-skilled employment" (Commission of the European Communities 2009). Enabling and digital technologies are playing an increasingly important role for companies, science and policy makers. Technologies such as robotics, artificial intelligence and additive manufacturing will have strong implications on the structure and management of future supply chains through all industrial sectors (Radanliev et al. 2019; Holmström et al. 2016).

These enabling technologies are not the only factor determining supply chain competitiveness, but they can be one of the key factors for increasing it and applying a specific supply chain strategy (Prajogo and Olhager 2012). Implementing technologies can have an important impact on improving the agility, transparency or reliability of a supply chain (Qrunfleh and Tarafdar 2014). However, supply chain performance also depends on other framework conditions and decisions.

Open innovation is recognised as a critical tool for accelerating growth, and the rapid pace of change in emerging technology markets heightens the importance of scouting and incorporating technologies from the innovation ecosystem (Curley and Salmelin 2013; Rohrbeck et al. 2009). Using a scouting process based on the open innovation paradigm, technology and sector experts were involved in the identification of new technologies necessary to support supply chain evolution until 2030. The technology scouting presented in this chapter aims to identify enabling technologies for supply chains in three industry sectors: discrete manufacturing, the process industry and logistics and distribution. This is achieved through the analysis of existing roadmaps and studies regarding enabling technologies.

Technology scouting is a method for technology foresight analysis (Gudanowska 2014). Technology scouting can be described as the process of collecting knowledge on science and technology at an early stage by using formal and informal information sources including expert knowledge (Gudanowska 2014). It can be used to gather information on specific technological areas or in explorative ways to identify relevant developments (Rohrbeck 2010). Technology scouting includes the process steps of identification, selection and assessment. The main objectives of the technology scouting approach are the early identification of technology trends and the recognition of challenges and opportunities of the technologies (Rohrbeck 2010). Additionally, technology scouting constitutes the precedent stage of technology mapping, which will be conducted in a later stage of this research.

This chapter follows a concise structure, with an introduction to enabling technologies and scouting methodology in Sect. 1. The technology scouting methodology is depicted in Sect. 2, which includes the identification and the selection of the enabling technologies as well as the assessment methodology. According to the methodology, Sect. 3 presents a full set of 18 enabling technologies that have been identified, combined with their implementation challenges and industrial impact scoring. Finally, Sect. 4 draws conclusions for the chapter, which also depicts future avenues of research.

2 Methodological Approach for Technology Scouting

The technology scouting was conducted as a 3-step process comprising the phases identification, selection and assessment as shown in Fig. 1. This figure presents the general identification, selection and assessment approaches, including five of the analysed technology roadmaps as an example. Figure shows the following four representative studies analysed for the identification of enabling technologies (*Identification*): VDMA Future Business Trends (VDMA Future Business 2016), the Digital Transformation Scoreboard (European Commission 2017a) and the DHL Logistics Trend Radar (Chung et al. 2018) and Visions of the Future: Transportation and Logistics 2030 (Clausen et al. 2014) as logistics sector studies. The 18 enabling technologies that were selected are listed in the middle of the figure and described in Section 2.3 (*Selection*). The methodology for the third step (*Assessment*) is described

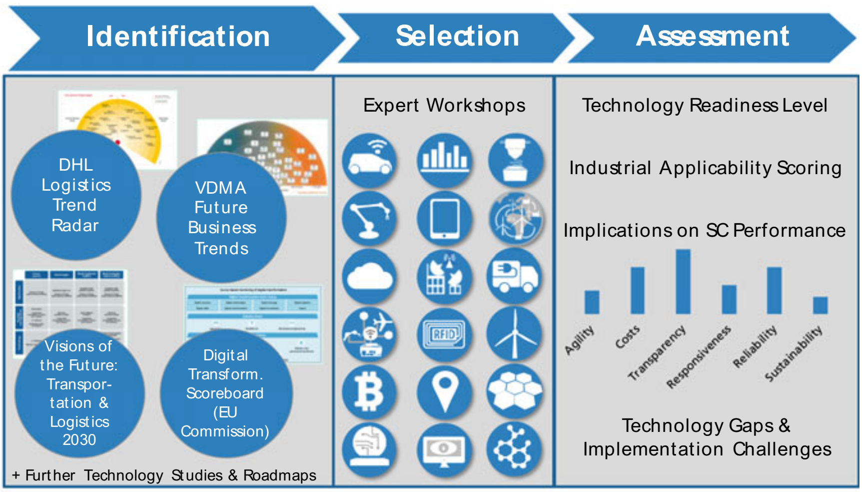

Fig. 1 Methodological approach for technology scouting

in detail after that. The figure also illustrates that, from a large number of technologies (over 60), 18 enabling technologies were ultimately selected and assessed.

In the following, each step of the methodological approach for the technology scouting is explained in more detail.

Identification

In order to identify enabling technologies, existing roadmaps and studies at different levels (regional, national, international and sector-specific) were analysed for this work. Nearly 400 technology and sector studies and roadmaps were reviewed by the project partners, including scientific papers, reports and grey literature, with the intent of identifying enabling technologies for supply chains. Moreover, more than 60 current projects were taken into account considering the main EU programs, such as SPIRE—Sustainable Process Industry through Resource and Energy Efficiency (SPIRE 2020) and FOF—Factories of the Future (EFFRA 2020), TRANSPORT (European Commission 2020b) and ICT (European Commission 2020a) as well as other related programs, such as Interreg (Interreg Europe 2020) and Regional Funds. Over 60 technologies were identified in this first step of the technology scouting.

Table 1 shows an extract from the most relevant literature for the three sectors of discrete manufacturing, the process industry and logistics and distribution.

Selection

In the selection phase, experts from the three sectors of discrete manufacturing, the process industry and logistics and distribution were invited to workshops to select and cluster the enabling technologies. Each project partner first conducted an internal workshop for this purpose. Subsequently, a joint project meeting served to select the most important enabling technologies for future supply chains. As a result, 18 enabling technologies were selected using the technologies identified in the previous identification step. This was achieved by clustering similar technologies and classifying sub-technologies within the 18 enabling technologies.

Assessment Methodology

In order to evaluate and validate the 18 enabling technologies that had been selected, a technology assessment methodology was performed for each technology with input

Table 1 Most relevant references for the industrial sectors

Sector	References
Discrete Manufacturing	Berkers and Jansen (2017), European Commission (2014), European Commission (2017a), Hallward-Driemeier and Nayyar (2017), UNIDO (2016)
Process Industry	Berkers and Jansen (2017), (DHL Customer Solutions & Innovation 2017), (European Commission 2017a), Roland Berger (2017), (SPIRE)
Logistics and Distribution	ALICE (2015), Clausen et al. (2014), Deloitte (2017), Chung et al. (2018), Kersten et al. (2017)

from about 30 project experts from the three sectors, and a literature review was also carried out. For the assessment of the enabling technologies, different dimensions were considered to evaluate the identified enabling technologies:

- industrial applicability scoring for the three relevant sectors (discrete manufacturing, the process industry and logistics) and
- implications on supply chain performance based on six criteria.

The assessment dimensions also included a gap analysis of technological gaps and implementation challenges.

Implications on Supply Chain Performance For the evaluation of the implications of each technology on supply chain performance, six criteria based on the SCOR performance attributes (Apics for Business 2019) and the Roland Berger Supply Chain Excellence Study (Roland Berger 2015) served as indicators. Amongst them, the criteria agility, costs, responsiveness and reliability are included in the SCOR performance attributes (Apics for Business 2019). The criteria transparency and sustainability chosen from the Roland Berger Supply Chain Excellence Study (Roland Berger 2015) expand the economic view of the SCOR performance attributes to macro-economic aspects and thus complete the comprehensive view of the implications on supply chain performance.

The following six criteria were defined for the supply chain performance evaluation:

- *Agility*: Agility is defined as the ability to react to external influences and marketplace changes in order to achieve or maintain competitive advantages. The criterion includes flexibility and adaptability (Apics for Business 2019).
- *Costs*: The costs criterion refers to the cost of operating the supply chain processes such as labour costs, material costs, management and transportation costs. A typical cost metric is Cost of Goods Sold (Apics for Business 2019).
- *Transparency/Traceability*: This criterion describes the ability to track a product's flow throughout the production process and supply chain (Doorey 2011; Egels-Zandén et al. 2015; Laudal 2010; Roland Berger 2015).
- *Responsiveness*: Responsiveness describes the speed at which a supply chain provides products to the customer. One metric for responsiveness is the cycle-time (Apics for Business 2019).
- *Reliability*: Reliability is defined as the ability to perform tasks according to expectations and thus emphasises the predictability of the process output. Metrics for this criterion are, for example: On-time, the right quantity, the right quality (Apics for Business 2019).
- *Sustainability*: The criterion of sustainability is defined in line with the UN Sustainable Development Goals: esp. 7—Affordable and Clean Energy; 9—Industry, Innovation and Infrastructure; and 12—Responsible Consumption and Production (Roland Berger 2015; United Nations 2015).

For each of the six criteria, the scoring for evaluating the implication on SC performance was based on a scale from 1 to 5, whereby a score of 1 means that the technology has strongly negative implications on SC performance regarding the application examples, while a score of 5 implies that the technology has strongly positive implications on SC performance:

1. Strongly negative implications on this criterion are expected
2. Slightly negative implications on this criterion are expected
3. Neutral implications on this criterion are expected
4. Positive implications on this criterion are expected
5. Strongly positive implications on this criterion are expected.

Applicability Scoring

The applicability scoring refers to the extent of the applications of a specific technology in the three sectors. The applicability scoring in this work uses a scale from 1 to 4, whereby a score of 1 means that the technology is not widely applicable, while a score of 4 implies that the technology will have broad application throughout that industry sector:

1. No significant application cases are expected for this technology (*insignificant applicability*)
2. Applicability is limited to special application cases (*limited applicability*)
3. The technology will have several application cases (*moderate applicability*)
4. The technology will have *broad applicability* throughout the industry sector.

The experts rated each supply chain performance criterion on a scale from strongly negative to strongly positive for as well as the industrial applicability of each technology. Based on the ratings, the average value was determined for each sector. The implications on supply chain performance were described by the experts and determined based on literature reviews. Although a relatively high number of technologies were studied and processed numerically to some extent, the nature of this study remains largely qualitative due to the level of interpretation our experts deployed in the assessment tasks.

Gap Analysis

The gap analysis includes a definition of the technology gaps and the implementation challenges for each selected technology. A comparative analysis of literature, current European projects on these technologies and experts' opinions was carried out to arrive at a shared list of needs. Technology gaps consider technological issues which occur in the current application examples, and which may inhibit the expansion of the technology. The implementation challenges address all technological, organisational, cultural and processual barriers. Furthermore, some initial ideas for overcoming these barriers are provided.

3 Enabling Technologies for SC

In the first step of the methodology, technologies were identified by reviewing the technology and sector studies. These technologies were clustered and selected accordingly on the basis of expert workshops. The result of this selection process is the list of 18 enabling technologies shown in Fig. 2.

This list of the 18 enabling technologies represents one possible classification of the technologies related to supply chains in the three industrial sectors of discrete manufacturing, the process industry and logistics and distribution. This classification is based on numerous expert opinions from these sectors and an extensive literature review as presented in the previous sections.

Between the 18 enabling technologies that were defined there are important interrelationships and dependencies which are briefly addressed in the following subsections and will be further detailed in further stages of this research (especially in the context of mapping the technologies to the future supply chain scenarios).

The **Internet of Things** (IoT) comprises the autonomous collection and exchange of data from a network of physical devices embedded with sensors, software, network connectivity, and computer capability (PwC 2017). Especially for the manufacturing and logistics sectors, there is broad applicability of IoT. IoT enables easier and faster collection and processing of data to monitor critical parameters. Connected systems will lead to more agility and transparency in the supply chain (Moser 2015; Prasse et al. 2014). Enabling better decision making and process optimisation, the IoT will reduce costs and result in more efficient use of resources (Prasse et al. 2014).

Distributed Ledger/Blockchain The decentralised character of blockchain technology ensures high reliability, enables non-restrictive data transparency throughout the entire supply chain, and allows standardised and transparent business processes (Liang et al. 2017; Jakob et al. 2018). By reducing settlement time as the need for intermediaries is eliminated, and due to the increased and faster sharing of information and the instant access to data, this technology will improve the agility and

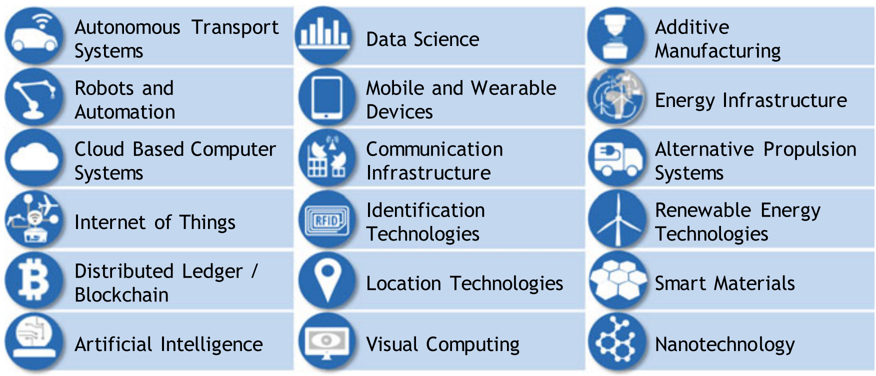

Fig. 2 List of the 18 enabling technologies

responsiveness of supply chains across all sectors (Dieterich et al. 2017; Jakob et al. 2018). Combined with IoT, this technology is critical for the development of future supply chains, especially in the logistics sector.

Data Science can be defined as the application of quantitative and qualitative methods to solve relevant problems and predict outcomes using algorithms aimed at creating or extracting new information out of vast amounts of data (Cao 2017). The technology will have broad applicability over the three industrial sectors. With large amounts of data available and the ability and willingness to share them efficiently, there will be an improvement of agility and process transparency in supply chains. Costs will be affected positively by more accurate forecasting and the prevention of disruptions (Wang et al. 2016). On the other hand, costs will be affected slightly negatively due to the need to collect and store the data. The negative effects will swiftly decrease as technology advances (Mcafee and Brynjolfsson 2012).

Artificial Intelligence (AI) will greatly affect the performance and development of the future SC industry given its central role in autonomous systems, robots and data science (Chui et al. 2018). Especially for the manufacturing and the logistics sector, the applicability of AI is broad. The implications on SC performance are mostly positive, but transparency may suffer as complex models and algorithms are often seen as a black box and decisions cannot be retraced (Dickson 2017; iapp 2017; Kuang 2018). Nevertheless, AI has the potential to decrease inventory, transportation, labour and disruption management costs due to cycle time and scrap reductions and to improve resource utilisation (McKinsey 2017).

Identification Technologies focus on identifying and tracking goods by using different codes or tags. The sub-technologies such as Radio Frequency Identification (RFID) and barcodes show broad applicability in the logistics sector and positive implications on SC performance, especially with regard to transparency, agility and reliability (Zhu et al. 2012).

Location Technologies are complementary to identification technologies: seamless positioning and tracking capabilities in both outdoor and indoor environments are an important requirement especially for the logistics and distribution sector (Mautz 2012). Real-time location of items during the whole process and real-time information sharing will enable transparency, and have positive implications on the whole supply chain (TexTrace 2016).

Additive Manufacturing (AM) is a technology enabling the creation of lighter, stronger parts and systems through transformative approaches to industrial production. It is considered a genuinely disruptive technology that supports customization while also minimizing waste due to more efficient use of resources (Boon and van Wee 2017). With these characteristics, AM is also seen as a critical technology for the development and improvement of future supply chains with a focus on manufacturing and the logistics industry.

Autonomous Transport Systems Comprising the sub-technologies of autonomous vehicles (e.g. trucks, trains and ships) and drones, the technology has broad applicability across all industrial sectors. Autonomous transport systems will create opportunities to reduce costs and increase reliability and sustainability by improving resource efficiency due to emissions reductions, fuel efficient driving, improvement of traffic and most likely fewer accidents (Heard et al. 2018; Bugdahn 2017; Chung et al. 2018). Furthermore, the technology will lead to more agility due to easily reconfigurable systems and to increased transparency due to better communication in real-time between and within the systems (Nowak et al. 2016).

Cloud Based Computer Systems are becoming more pervasive in large-scale supply chains as enterprises look to gain agility and speed in resolving complex problems through more effective collaboration (Columbus 2014). Due to easier sharing and processing of information and (real-time) data between different supply chain partners, cloud based computer systems provide opportunities to decrease costs and gain more visibility and transparency (Agorasti Toka et al. 2013). Especially in the logistics sector, there are many application examples and broad applicability of the technology.

Communication Infrastructure aggregates networks and protocols required for the establishment of viable communication between two or more IoT components. The current main sub-technologies are 5G and NarrowBand-IoT (NB-IoT). Since communication infrastructure enables all digitalized technologies it is one of the key enabling technologies for future industrial supply chains (Rao and Prasad 2018; Fettweis 2016). For the three sectors, applicability is moderate to broad and there are positive implications on SC performance for all six criteria.

Robots with their superior sensor technology, control and intelligence, especially in combination with artificial intelligence, have the ability to automate or support human activities and thus have a strong influence on the labour market (Wisskirchen et al. 2017). Main sub-technologies for robots include collaborative robots, which physically interact with humans in shared environments, and autonomous robots, designed for self-reliance and being capable of operating without human assistance or interaction (Djuric et al. 2016). Robots have broad applicability especially in the manufacturing and logistics sector with positive implications on agility and costs (DHL Customer Solutions and Innovation 2016).

Mobile and Wearable Devices are devices which can act autonomously, are non-invasive and perform specific functions, such as monitoring and support over a prolonged time-period. Application examples with broad applicability in all three industrial sectors and positive implications on transparency (Hao and Helo 2017) are smart glasses and smart gloves for barcode scanning.

Visual Computing pursues the goal of extracting information from images and embedding information in images, using image- and model-based information technology by combining computer graphics and computer vision (Fraunhofer IGD

2018). Sub-technologies like augmented reality (AR) and virtual reality (VR) have broad applicability in the logistics sector, resulting primarily in positive implications regarding transparency (Chung et al. 2018).

Energy Infrastructure technology is designed to provide reliable energy coverage while also optimising energy consumption (Goldthau 2014). Sub-technologies such as smart and neural grids, which mainly focus on the generation, storage and consumption of electric energy, and battery energy storage systems (BESS), which are aimed towards storage capabilities of the grid, are largely still at basic research level and are aiming to have positive implications on the sustainability of future supply chains, especially in the manufacturing sector.

Alternative Propulsion Systems comprise all propulsion engines which use alternative means of propulsion when compared to petroleum-based fuels. Therefore, this technology encompasses advanced biofuels and electromobility enabling overall sustainability of the future transport sector (IRENA 2016; Storch and Scharrenberg 2019).

Renewable Energy Technologies are aimed at establishing renewable energy resources as the main sources for energy systems. To achieve the EU's objectives for 2030 to reduce greenhouse gas emissions by 40% compared to 1990 levels (European Commission 2018), technologies such as flywheel energy storage, hydrogen production and storage technology, and advanced biofuels have to be used increasingly. In addition to the positive implications for the sustainability of supply chains, these technologies can also lead to long-term cost savings (International Energy Agency 2014).

Smart Materials are magnetically or electrically controllable materials with outstanding mechanical properties. These materials play an increasingly important role in the development of innovative, versatile and efficient products with a wide range of new functions (Fraunhofer ISC 2018). The positive implications on supply chain performance were assessed as relatively low, but there is broad applicability in the manufacturing sector.

Nanotechnology uses material modifications at the atomic, molecular and supramolecular level to improve functional systems at the molecular level and to design objects with a bottom-up approach aimed at creating sophisticated products (Dwivedi and Dwivedi 2012). With these properties nanotechnology has broad applicability in the manufacturing sector with possible positive implications on costs, reliability and sustainability (National Nanotechnology Initiative; Okoli et al. 2013).

3.1 Assessment of the Enabling Technologies

In order to evaluate and visualize the significance of the respective technology, the assessment matrix shown in Fig. 3 is based on the mean scoring for the implications

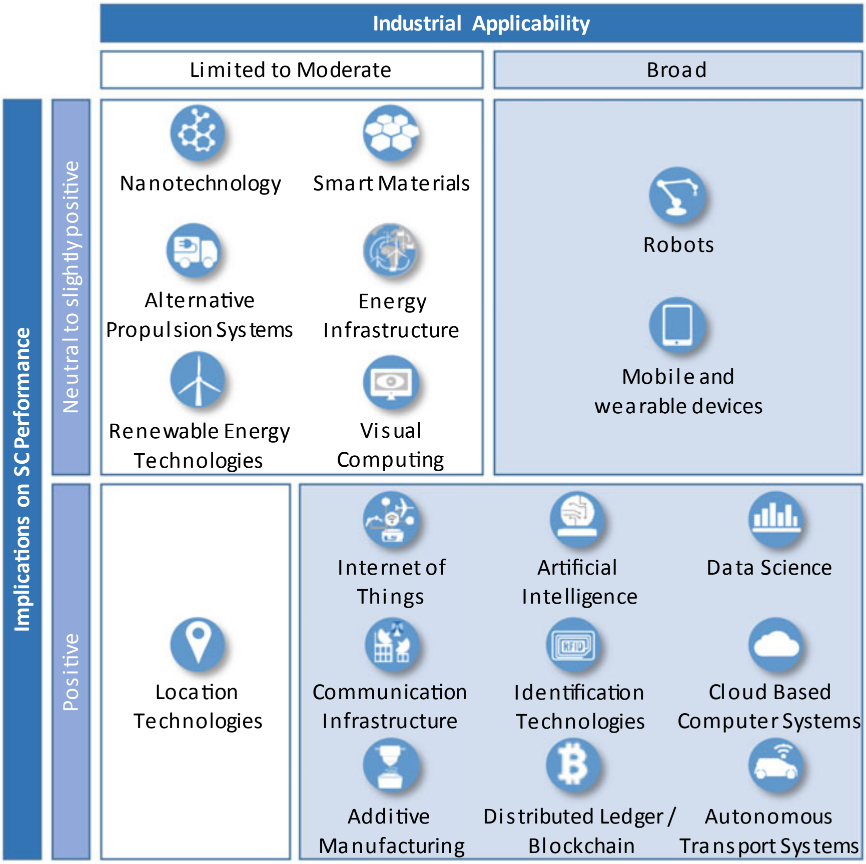

Fig. 3 Assessment of the 18 enabling technologies (implications on SC performance and industrial applicability)

on SC performance for all six criteria and the mean scoring related to applicability over all three sectors for each technology. Figure only shows the quadrants of the assessment matrix where the 18 enabling technologies are positioned, since all of them have at least a limited applicability and neutral implications on SC performance.

The predominantly positive assessments of each technology show that they have the potential to influence future supply chains in a relevant way. Based on this assessment, nine technologies with broad industrial applicability and the most positive implications on the supply chain performance over all three industry sectors were highlighted as key enabling technologies for future research and development: Internet of Things, Artificial Intelligence, Data Science, Communication Infrastructure, Identification Technologies, Cloud Based Computer Systems, Additive Manufacturing, Distributed Ledger/Blockchain and Autonomous Transport Systems.

It is important to emphasize that the 18 technologies presented here are fundamentally complementary, and that combinations and systems of these technologies therefore enable stronger capability for future supply chains (Sanjiv 2017). This means that the effects of technologies can be more powerful when used as an overarching system. Therefore, further research is necessary for a more comprehensive and complementary analysis of groups of technologies applied to specific supply chain models and dimensions

3.2 Main Implementation Challenges

The gap analysis of the technologies revealed some frequent technology gaps and implementation challenges of the respective technologies. These mainly concern standardisation and interoperability and, for a wide range of technologies, data storage, availability, quality and accessibility as well as further processing of these data (e.g. in the form of algorithms).

In fact, system integration is one of the most important implementation challenges identified in nearly all enabling technologies that will enable cross-company, universal data-integration networks with different subsystems, including hardware, software and communications, that need to be integrated (Boston Consulting Group 2018; Gartner IT Glossary 2018; Zhong et al. 2016). System integration should be carried out both horizontally and vertically ensuring different types of collaboration at different levels of supply chains. Vertical integration focuses on integrating processes across the entire organisation via the networking of smart production systems, smart products and smart logistics, whereas horizontal integration encompasses networking along the entire supply chain, from suppliers and business partners to customers, in order to achieve seamless cooperation between companies (Werner 2017).

Due to increased data exchange and connectivity, there is a growing requirement for systems protection with the aid of cyber security (Boston Consulting Group 2018; Radanliev et al. 2019; Bekara 2014). Therefore, appropriate secure and reliable levels of protection regarding the identity and access management of machines, networks, clouds and users have to be ensured with advanced systems such as firewalls, DNS filtering, malware protection and antivirus software (Boston Consulting Group 2018; Gartner 2018).

It is expected that, with respect to SC models, some technologies only influence operations without influencing the structure of the SC or revenue mechanism, while others affect core production and distribution capacity and require a redesign of the supply chain network itself.

4 Conclusion

This chapter identified 18 enabling technologies for the supply chains of the future until 2030 for the three industrial sectors: discrete manufacturing, the process industry and logistics and distribution. The methodology applied was based on a technology scouting approach. A set of enabling technologies was identified by means of a literature review (analysis of existing technology roadmaps and studies), and further clustered into the 18 technologies presented, which were subsequently evaluated using an assessment methodology. The enabling technologies were highlighted for future research and development based on industrial applicability, the implications on supply chain performance and the gap analysis. The main implementation challenges at SC level were identified in system integration and cyber security systems.

The list and assessment of the enabling technologies can be understood as an overview for future technological developments relevant to SC management and may also help companies to focus on the implementation of relevant technologies. Further stages of this research will carry out a mapping methodology to combine the identified enabling technologies with the supply chain strategies which will represent support for the identification and definition of the research and innovation topics depicted in a strategic research agenda.

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Mapping Enabling Technologies for Supply Chains with Future Scenarios

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Abstract Driven by the current digital transformation, European companies rely on accurate forecasting of future trends and prediction of most useful technologies in order to maintain their competitive edge. For this purpose, the mapping of enabling technologies to future scenarios becomes a valuable tool for practitioners and researchers alike, especially when considering the disruptive events that surround SCs design, implementation and management. This research sets forth to fill this gap by presenting a technology mapping of enabling technologies based on technology portfolio approach, expert elicitation and literature. The final outcome is the mapping of the enabling technologies to the characteristics of the future European SC scenarios.

Keywords Enabling technologies · Supply chain strategies · Technology mapping

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1 Introduction

On recent years, great attention has been given to robotics, Artificial Intelligence (AI), computer science, big data and other digital technologies (Lee et al. 2014; Mosterman and Zander 2016; Khorram et al. 2017). These technologies are changing the discrete manufacturing, process and logistics & distribution industrial sectors. Some recent attempts have been done to shed light on their application regarding the SC level, such as: (a) link between Industry 4.0 and lean production (Buer et al. 2018); (b) importance of Internet of Things (IoT) on SC management; (c) the impact of 3D printing on SC processes and performances (Liu et al. 2014; Oettmeier and Hofmann 2016; Li et al. 2017); and, (d) the change in short-term SC scheduling in smart factories (Ivanov et al. 2016).

These technologies have the potential to revolutionise operations and SC management (Brennan et al. 2015; Holmström et al. 2016; Rüßmann et al. 2015) by focusing on future customer demands, effective resource management and data generation and exchange. This will enable the creation of a product, or delivering a service, in a faster, cheaper, more efficient and more sustainable fashion. Companies are making increasing efforts to improve their own processes. Nevertheless, currently more than ever, it is important to "open the doors" and have an integrated approach with upstream and downstream supply chains (SC) bearing new strategies as well as appropriate technological support.

Considering the growing relevance of technologies for SC and specially their large and broad expected impact, this chapter aims at: (1) mapping the enabling technologies with the SC of the future scenarios which were identified and discussed in Stute et al. (2020) and, (2) mapping the technologies that are expected to contribute to the SC strategic dimensions. This was achieved using the technology mapping methodology, based on the technology portfolio approach and the use of Table Management Tool, expert elicitation, and through literature review.

SC competitiveness is determined by several key factors such as selection of raw materials, SC partners, choice of markets and service offering strategies and technology. Therefore, these factors have crucial implications on the development and improvement of SC performance (mostly linked to enhancements of agility, transparency, reliability and sustainability). These implications support the choice of different enabling technologies aimed at distinct SC strategies, thus providing the technology mapping presented as the result of this chapter.

The chapter has the following structure. The methodology used is presented in Sect. 2. The technology mapping for each specific future SC scenario is detailed in Sect. 3. The overview of the technology mapping is presented in Sect. 4, and the conclusions are portrayed in Sect. 5.

2 Methodology

Technology management research field, which encompasses technology foresight and technology forecasting research, can be organized with respect to the use of technology in business strategies and operations. This entails the connection between engineering, science and management disciplines focused on development and implementation of technological capabilities for accomplishing strategic and operational objectives (Council 1987). It is, therefore, a merge between operations management and industrial technology, with activities aimed at production and operations management, project management, quality control and general management principles (ATMAE—The Association of Technology 2009).

Technology mapping methodologies are part of technology foresight research (Chen et al. 2012; Gudanowska 2016), and are the focus of this chapter, which aims to describe the methodological stages for achieving the intended mapping of enabling technologies onto the SC strategies of future scenarios. Therefore, these technology mapping methodologies are discussed in more detail on subsections below, first through a brief introduction of the concept and overview of technology foresight, followed by the detailed stages required on technology mapping methodologies, while also presenting the methodological framework used in this chapter.

The overall scheme highlighting the main steps to achieve the intended results can be observed in Fig. 1.

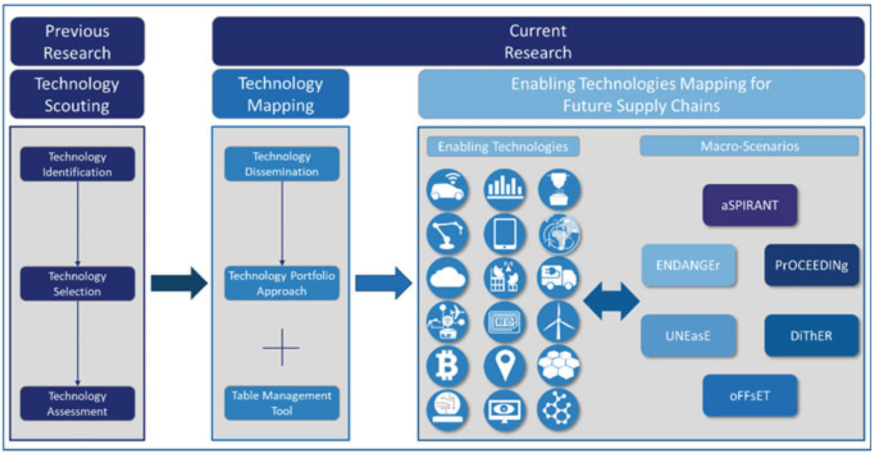

Fig. 1 Methodological framework for this study

2.1 Technology Foresight—Concept and Overview

The main assumption of technology foresight is the presence of interested stakeholders' groups aimed at taking meaningful action and being open minded to innovative ideas (Gudanowska 2016). In other words, foresight is an attempt at linking observations of shift dynamics with current decision-making and indicating possible development schemes for a future state beforehand (Warnke and Heimeriks 2008). Hence, a research can be characterized inside the technological foresight research area whenever the goal is the development of technological solutions or needs, incurring on the development of that research area.

Methods used for technology foresight are vast within a specialized literature (Porter 2010), such as workshops, technology watch, bibliometrics, surveys, growth curve modelling, requirements analysis, quantitatively based scenarios, Data Envelopment Analysis (DEA) and trend impact analysis. Since technology management and technology foresight belong to the field of strategic decision-making, they involve the use of prioritization methods, which may facilitate decision-making based on different alternatives or on different scenarios and strategies, as in this research (Gudanowska 2016). Technology scouting and mapping are methodologies belonging to the technology foresight research field, and are complementary to each other with the common goal to portray technologies for a given activity, process and/or objective (Gudanowska 2014, 2016).

Scientific literature breaks the process of technology mapping into phases, or functions, with a general agreement of requiring at least four of these functions: Technology Identification (TI), Technology Selection (TS), Technology Assessment (TA) and Technology Dissemination (TD; Rohrbeck et al. 2006). TI, TS and TA functions have been presented in Stute et al. (2020), in the scouting of 18 enabling technologies (Arasti and Moghaddam 2010; Rohrbeck et al. 2006).

2.2 Technology Mapping

Technology mapping allows for a qualitative analysis of technologies and to examine analogies among them. On this perspective, it is important that these analyses take place with the same rigor as the structured approach to collect information about each technology, and aim towards presenting a justified image of their current and future states (Roper et al. 2011). Therefore, this methodology should favour an analytic work focused at expanding the gathered knowledge while making its interpretation easier, in order to distinguish such method from a simple review and record of the data on technologies (Gudanowska 2016).

In order to establish technological development trends, it is essential to determine the current state of technology development and the elements related to such technology. Bearing this goal in mind, accounting for the evolution of technological foresight research based on future-oriented technology analysis is crucial (Cagnin et al.

2013). The switch from foresight research to general future analysis to technology focus on future analysis is the basis for diagnostic activities. Technology mapping stands under this new vision of technology foresight among other methods, bearing applications that enhance the process of technology identification and gather most knowledge regarding distinguished technologies, which are used in the technology selection process (Gudanowska 2016).

Technology mapping usually focuses on a sector or an area, being a convenient method for identifying technologies when various firms or industries with different characteristics are considered, as well as multiple products/services for a large number of customers (Khalil 2000). As depicted previously, technology mapping methodology has a four-phase methodological approach for achieving a well-devised Technology Strategy Formulation (Arasti and Moghaddam 2010; Gudanowska 2016; Rohrbeck et al. 2006). This chapter focuses on the fourth and final phase of the methodological route of technology mapping, known as Technology Dissemination (TD); (Rohrbeck et al. 2006). For the purposes of this research, TD's objective is to provide the combination of the identified enabling technologies with the SC strategies and future scenarios in an overview fashion that is useful for companies when adapting to the different contexts and SC strategies.

It is important to stress that the TD phase is a high level stage of the methodological approach for technology mapping. Among others, the methodologies within the technology portfolio approach were considered adequate for this study due to their objective being the cross-referencing of technologies and dimensions for specific conditions (Rohrbeck et al. 2006; Phaal et al. 2006). From these, the approach based on Table Management Tool was selected, with the intention to achieve the final technology mapping and to be consistent with the methodology used for establishing the enabling technologies depicted in Stute et al. (2020) of this book (Phaal et al. 2006).

The table management tool herein used aims to provide information on the combination between technologies and the SC future scenarios or strategies (Phaal et al. 2006). For this purpose, the axes were divided into a number of distinct and specific categories, which, when combined with expert elicitation techniques, permit precise mapping of enabling technologies considering the future scenarios' characteristics and the strategies envisioned for the particular contexts. In our case, we have first mapped the technologies according to the scenario's strategic dimensions, which are: products and services; sourcing and distribution; supply chain configuration; manufacturing systems; sales channels; and sustainability. The scenario's technology mapping derived in this step represents the technological evaluation of each future scenario based on its characteristics, and the related level of adoption of the enabling technologies applied and it has been defined as the scenario technology profile. After this, the different scenario technology profiles were used for a cross-scenario comparison, depicted in Sect. 4, which enabled to classify the profiles, according to their technological level into four different categories: (a) digital masters—wide adoption of most, if not all, enabling technologies; (b) tech fashionistas—reasonable adoption of multiple enabling technologies; (c) tech beginners—low adoption of

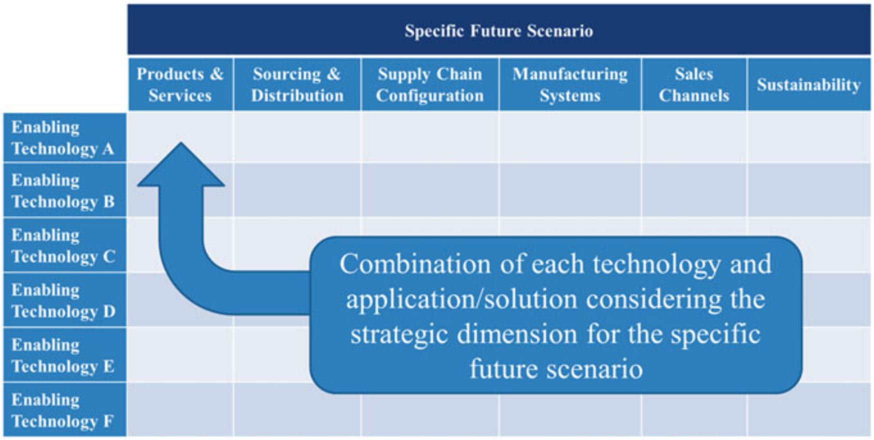

Fig. 2 Structure of technology mapping table for specific future scenario

enabling technologies; (d) tech conservatives—very low, if any, adoption of enabling technologies.

Overall, six tables, one for each future scenario, were prepared following the structure depicted in Fig. 2. The inputs used for the expert elicitation and combinatorial work were: (i) the 18 identified enabling technologies, as presented in Stute et al. (2020); and (ii) the characteristics of the future SC scenarios depicted in Sardesai et al. (2020)—considering the strategic dimensions and SC strategies (identified in Barros et al. 2020).

The results of the technology mapping done for each future scenario are shown in the following section.

3 Technology Mapping for the Supply Chains of Future Scenarios

The methodology abovementioned was applied to each of the future scenarios and is depicted separately on the following subsections. The paragraphs describe the mapping of technologies on the basis of each scenario's characteristics and are depicted according to the scenario's strategic dimensions previously mentioned.

3.1 Technologies for the Supply Chains of Scenario "aSPIRANT"

In the "aSPIRANT" scenario, cyber-physical SC networks, heterogeneous nature of sourcing operations, and new market-shaping business models will require development and application of intelligent, complex, interdependent, and end-to-end technology solutions for the SC.

The "aSPIRANT" scenario displays a SC with low uncertainty in demand, while the supply is associated with the predictability of market fluctuations regarding products and services provided. In this sense, advanced technologies that optimize the responsiveness, reliability, and transparency/traceability performance-attributes of SC organizations are considered of crucial importance at the production level. Examples of these advanced technologies include: Artificial Intelligence (e.g. machine learning, deep learning), Data Science (e.g. Big Data Analytics), Autonomous Transport Systems (e.g. drones), and converged usage of heterogeneous technologies, combining industrial IoT connectivity systems, artificial intelligence, and collaborative/autonomous robotics. In the scenario context, digital lean manufacturing systems, allowing for high volume and low complexity production processes, need to be supported and maintained along with enabling technologies.

Moreover, efficient integration of digital technologies (automated control systems, industrial connectivity solutions, and information-tracking systems) with energy and waste management infrastructures of manufacturing facilities will be highly important in the effort to improve on-demand energy supply for production facilities and to minimize waste volume in an eco-friendly manner. In this context, the complementarity of digital technologies depicted on this SC scenario enhance operational scalability and servitisation ecosystem of manufacturing facilities.

As for the business process management in sourcing and distribution, integration of intelligent encrypted contract solutions, cloud-based Business Process as a Service (BPaaS), Platform as a Service (PaaS) and Software as a Service (SaaS), and predictive data analytics into procurement organizations will increase SC agility and decrease operational/transactional costs. Furthermore, to build omnichannel excellence, procurement organizations are required to find smart implementation techniques of servitisation technologies, while leveraging Artificial Intelligence with industrial IoT and high-performance computing solutions. In addition, location technologies will be useful for tracking and traceability of goods and shipments, being capable of suggesting optimal location to consumers where it is possible to collect their orders and inform about multiple delivery systems (Deloitte 2015). Moreover, Visual Computing (e.g. Augmented Reality) is going to provide customers with a seamless omnichannel experience by closing the channel gap at various online and offline touch points. For example, it allows to animate products or their packaging, de-saturating products in the physical assortment, to personalize their choice set, offering better price comparisons (Hilken et al. 2018).

In the context of closed-loop SC systems and lean manufacturing environments, there are various types of waste streams that will emerge within production: transport, inventory, motion, waiting time, over-processing, over-production, and defects. Integration of identification technologies and location technologies within the manufacturing facilities may increase efficiency in tracking waste streams in the production plants, while also providing service verification and productivity data on manufacturing waste inventory. On the other hand, cloud computing systems, also for Enterprise Resource Planning (ERP) solutions, might help to structure and tailor resource management behaviour of a procurement organization into a closed-loop business process flow. As for the impact of green technologies in manufacturing and process industry, it is difficult to depict, explicitly, technology use development paths in integrating these solutions within the existing manufacturing and processing infrastructure, as there is no one-size-fits-all business model enabling energy efficiency in industrial settings.

In this scenario, cloud-based computing systems will be used at different scales. The cloud-based computing, particularly manufacturing execution systems and ERP-enabled operations' management technologies, leveraged by the use of AI and advanced algorithmics, may increase investment in advanced solutions for energy management on the factory floor. At the logistics level, cloud-based SaaS solutions enable further the automation of inventory solutions, open direct sales channels, and develop further personalized shipping solutions.

Additive manufacturing and innovative energy infrastructure will lead to achieve this transition towards a closed-loop and green SC. The emergence of smart materials, as well as of renewable and new energy sources, will be great assets to accomplish this objective. Smart materials, for instance, can be applied in smart green roofs for insulation, thus improving thermal performance and reducing the energy consumption (Mohamed 2017). Similarly, they may be used as devices for temperature changes sensing, which can be shown through colour response capabilities, thus being especially important in emergency situations inside factories, industries and public buildings (Makakli 2017). Furthermore, alternative propulsion systems will greatly participate to this transition. The use of IoT aids companies towards achieving better understanding of the current suppliers' performance, while frequently tracking and benchmarking performance over time. This is also true when considering sustainability aspects, such as real-time carbon footprint monitoring, combined with vendor/suppliers' historical performance and sustainability data collection, through the use of Blockchain technologies, for providing improvements on sustainability performance (Kouhizadeh and Sarkis 2018). Moreover, the use of Visual Computing technologies such as VR and AR can contribute to increase operators' capabilities by creating a virtual environment that simulates the plant design or specifics tasks (Mattson et al. 2018).

The future emergence of smart contracts and Blockchain will enable to face the challenge related to the legal dimension. This would be associated with the communication infrastructure. Development of sensors and their accuracy will lead to predominance of smart maintenance and aid on the development of the green SC. In addition, the use of 5G as network backbone for IoT and digital technologies greatly improves traffic management in urban areas, thus reducing traffic congestion, driving time and vehicular pollutants (West 2016).

3.2 Technologies for the Supply Chains of Scenario "PrOCEEDINg"

The "PrOCEEDINg" scenario presents a customization-driven market, diverse sourcing and distribution operations, and the increasing focus on individualism aided by the DIY society, all of which will require SC strategies with fast response-time, posing leagile characteristics, while also being complex and interdependent in nature.

Since the SC for the "PrOCEEDINg" scenario presents predictable demand and supply combined with customized products and servitisation and the presence of high levels of digitalisation, it is paramount that the technologies herein focus on responsiveness, reliability, transparency and traceability, as well as flexibility performance-attributes regarding SC companies and industry sectors. Hence, the most important technologies would be Cloud Based Computer Systems (Platform as a Service—PaaS, Software as a Service—SaaS, Business Process as a Service—BPaaS and Infrastructure as a Service—IaaS are all applied for providing backbone into customization aided with servitisation) and Internet of Things (IoT; especially focusing on Cyber-Physical Systems—CPS). IoT is a key technology also for facing the rise of cybersecurity issues given the ever increasing need to rely on digitisation.

The customisation strategies are driven by the combination of high variety with small and medium production facilities, and by wide digital technologies' adoption. Thus, Hyperconnected Factories and Digital Mass Customization strategies are critical, greatly aided by the use of Autonomous Transport Systems (especially Autonomous Transports for last mile delivery) and Additive Manufacturing (with focus on 3D and 4D printing aimed at material extrusion capabilities, powder bed fusion, directed energy deposition and material jetting). These technologies are further supported by the implementation of IoT (through Process intelligence, machine to machine real-time communication and sensor technologies for devices in warehouses), as well as Communication Infrastructure (as provider of the backbone for the digitalisation process through enabling network communication technologies such as, 5G and NarrowBand-IoT). Furthermore, Energy Infrastructure (mostly focused on Smart Grids and Battery Energy Solutions Systems and Smart and Neural Grids) provides backbone to enable and enhance the afore mentioned technologies.

For a leagile SC, within this scenario, the use of autonomous transport systems and, more specifically, autonomous drones for maintenance and surveillance services are very important. Combined with autonomous robots, they will increase the reliability, responsiveness and in-line production of the SC, conferring it a lean characteristic. Moreover, the composition of an agile SC is enabled by: (i) the reduced use of resources such as energy; (ii) optimized available working space aided by

Data Science (especially predictive analytics); and (iii) AI focused on the customisation issues (supported by deep learning algorithms for product demand and SC forecasting).

Additionally, autonomous transports have a significant impact on global distribution through the use of Autonomous ships/vessels and trains, greatly improving reliability and flexibility of the SC distribution. On the other hand, Cloud based computer systems will support companies in handling global outsourcing, which may be achieved through the BPaaS. Cloud based computer systems also supports the omnichannel distribution (by means of SaaS in the form of process intelligence tools aimed at omnichannel monitoring of customer experience), due to the need for multiple channels with different characteristics.

The combination of Consumer to Consumer (C2C) with omnichannel approach requires the implementation of Cloud Based Computer Systems (BPaaS aimed at providing enterprise resource management solutions, and PaaS with focus on smart contract platform for cybersecurity reasons). The logistical issue is tackled using Autonomous Transport Systems with autonomous vehicles and drones for last mile delivery, and autonomous trucks for road freight transport, which greatly increase efficiency of the combined strategies. Moreover, Identification Technologies may provide valuable data about consumers and their interactions with products and services, as well as real-time inventory management. Therefore, they can lead to increase speed of refunds and replacements, which in turn enhances omnichannel responsiveness and reliability, greatly improving SC performance (Group 2018).

Lastly, given the growing concern surrounding circular economy capabilities, green SC and social-responsible strategies, Identification Technologies (i.e. for asset recovery and disposition aiding at minimizing costs and waste) and Location Technologies for object real-time detection and traffic information collection enable the decrease of environmental hazards on internal and external logistics (Kouhizadeh and Sarkis 2018). Additionally, the use of IoT, Cloud Based Computer Systems and Communication Infrastructure (all three technologies providing the backbone through enabling network communication technologies) will play a very important role in securing safe communication and data exchange on activities related to waste management and promoting circular economy in manufacturing environments. Moreover, Alternative Propulsion Systems (both through Advanced Biofuels and Electro Mobility) and Renewable Energy Technologies (Hydrogen Production and Storage, Advanced Biofuels and Automated solar panels cleaning systems) are all technologies that contribute, with increasing levels of importance, to the mitigation of waste generation, reduction of greenhouse gas effects and promotion of resource-efficiency strategies (Kouhizadeh and Sarkis 2018; Tsao et al. 2017).

Through data collection, that can be used to avoid excessive inventory, poor use of capacity, inactive and inefficient transportation and missed production schedules, IoT greatly improves SC closed-loop sustainability aspects (Parry et al. 2016). In addition, 5G network can provide faster data and improve traffic management in urban areas with more efficient route optimisation, especially when compared to current wireless technologies (West 2016). Also, Nanotechnology can be applied for energy savings and carbon emissions' reduction in the final product, further increasing SC sustainability performance (OECD 2013).

3.3 Technologies for the Supply Chains of Scenario "oFFsET"

The "oFFsET" scenario is characterized by the presence of open borders with reduced sales tariffs, enabling the implementation of an agile manufacturing system based on glocal sourcing and distribution. There is stagnation on digital transformation due to the lack of regulations, which inhibits sustainable development. Thus, the conventional and disruptive production technologies coexist, with global players playing major role, especially concerning financial innovations and constrained digital transformation aided by cyber-physical systems.

This scenario is characterized by the adoption of conservative technologies, such as identification technologies and location technologies used in warehousing activities, customer service functions and tracking for route optimization in freight supply and freight distribution. These types of technologies enable high agility levels particularly important for scenarios with uncertainty in demand and supply. In addition, modular production systems and agile manufacturing systems take advantage of identification technologies mainly for warehousing activities.

Glocal sourcing and distribution include the use of location technologies for the routing optimization. Moreover, products are delivered by means of traditional distribution channels.

Cloud based computer systems, only available for large and global players, will support the sourcing process given that companies have to handle glocal sourcing and distribution, which may be achieved through the Software as a Service (SaaS). Data science, by using the sub-technology predictive analytics, will be used for forecasting demand for mainstream products. High uncertainty in demand and supply requires a more agile SC with improved design, which greatly profits from the use of identification technologies, predictive analytics and advanced AI algorithms.

The use of 4G/LTE for consumer-behaviour adoption towards more efficient use of resources, as well as for providing faster data connectivity, thus enabling managerial decisions regarding resource-efficiency, are considered the communications' backbone for a resource-efficient SC implementation (West 2016).

3.4 Technologies for the Supply Chains of Scenario "DiThER"

The scenario "DiThER" is defined by an increasing influence of digital transformation, dynamic development of autonomous solutions, establishment of electrification technologies and green systems, the continuous exploitation of disruptive technologies and investment in smart cities. Still, the digital development is obstructed by stringent legal regulations, data management and privacy issues. The considered scenario is characterized by a high technological level in general (advanced digital features such as data science & IoT), but there is a lack of an overarching vision, coordination and cooperation in the SC.

For a leagile SC, which is relevant within this scenario, the use of digital technologies, such as data science and AI will be crucial for the agile adaptation of decisions and cost-efficient processes within the SC. Thus, the demand and SC forecasting and the resulting inventory optimisation with the support of predictive and prescriptive analytics and AI (e.g. machine and deep learning) will be a crucial factor to adapt to the uncertain and individual demand.

In order to develop a closed-loop SC, the use of alternative propulsion systems and renewable energy technologies will be very important. As smart cities become the norm in the scenario, the use of energy-efficient autonomous transport systems with alternative propulsion (e.g. advanced biofuels, electro mobility) will increase significantly. In this context, renewable energy technologies (e.g. advanced biofuels) will also be widespread.

Moreover, to implement the closed-loop SC, the use of IoT in the form of sensors and Machine-to-Machine (M2M) communication will represent an essential factor for capturing data on transportation logistics environment and enabling to connect in real-time production lines with SC processes.

The additive manufacturing (3D and 4D printing) will permit the increased individualization and development of a DIY society. Regarding the servitization, Cloud Based Computer Systems, such as Platform (PaaS), Software (SaaS) and Business Process as a Service (BPaaS), will play an important role enabling a digital platform economy.

For what concerns urban manufacturing systems, the use of collaborative and autonomous robots (e.g. smart transport robots), innovative energy infrastructure (e.g. smart and neural grids) and autonomous transport systems, such as autonomous vehicles (e.g. self-driving delivery robots) or drones for the last mile delivery will progress considerably.

The application of data science and AI will be a crucial factor in general for this scenario to enable the full potential of the urban living (e.g. smart routing).

3.5 Technologies for the SCs of Scenario "UNEasE"

An unstable political environment is the backbone of the "UNEasE" scenario, displaying a presence of protectionism, economic uncertainty and fragmentation of confederations. The lack of well-established regulations in various fields affects environmental and technological development, therefore, IP protection and customer data are at risk with low investments in cyber-security. Bearing obstacles regarding digital transformation, the agents rely solely on the traditional business to business environment, where traditional economy persists aided by the traditional production technologies. Disruptive technologies are implemented solely by big players, which set aside SMEs and Start-ups to compete exclusively on local markets, focusing mostly on customized products aimed at supporting the rise of DIY trends. Moreover, solutions are needed to face the dangerous effects of the climate changes and resource scarcity.

There are some features of the SC strategic dimensions in the "UNEasE" scenario that mainly influence the adoption of the technologies identified previously, like the low digitalization level in the society (including industry). In fact, in this scenario, the traditional economy persists due to the lagging of a clear legislation for data management which worsen a limited level of digitalization with a coexistence of traditional and new technologies. Moreover, there is a problem of unskilled workforce. This means that companies need to be supported in the implementation of new technologies with actions from public bodies that can create awareness through different training programs as well as directly support with actions to finance the introduction of new technologies. In particular, the following technologies can be useful to overcome challenges in this scenario.

Along a SC for customized products, as the one required in this scenario the use of some digital technologies, mainly in the down-stream side, is useful to improve the performance of the network. Companies should adopt technologies like Big Data Analytics and Business Intelligence to support the process of detecting customers' needs and changes in market demand. These technologies can enable to process in an efficient way the vast amount of data from markets and consumers and convert them into meaningful information. The aim is to create customers' profiles and identify new market trends to understand and possibly predict the high variability of the demand. This can have an indirect but positive impact on the management of the SC since these data can be processed in an efficient way to integrate the supplier role. Another technology consists in sensors to collect data for the realization of customized products and identify all the specific peculiar variants and characteristics required by different markets. Sensors are composed of integrated hardware (smart devices) and software (apps) and are configured with unique resource identifiers in Internet (Ding and Jiang 2016). Customers can interact with companies to express their feelings and opinions or co-create personalized products in social media: the interactions enable to capture their real needs. In the Business to Consumer (B2C) relationships these problems are overlapped thanks to the growing number of start-ups. Start-ups or Fintech companies in fact apply and develop technologies based on social sensors for improving relationships with customers as well as smart contract and mobile apps which support the rise of the sharing economy and improve the relationship between final customers and companies.

Among the production technologies ensuring flexibility and increasing the SC performances in terms of agility, responsiveness and reliability, additive and hybrid manufacturing represent the ones that can be more widely adopted in this scenario. 3D printing for example is a technology that can make the SC customer- driven, agile and also resource efficient because the amount of residual material or waste remaining after the process is significantly less than in subtractive manufacturing. Moreover, additive manufacturing is also a technology that fit well with the emerging urban manufacturing trend. In this scenario, the production phase must be indeed flexible and near located to the market, and the rise of small factories and FabLabs would support the DIY trend. In this sense, 3D-printing enables production of personalized products and components to be brought near to the customer in urban plants, or in specific service centres, available for customers willing to realize their own goods according to peculiar features. In this new urban setting, electric vehicles will be used equipped with location technologies, such as GPS tracking systems, which require well-developed communication infrastructure achievable with the implementation of 5G. The communication and location technologies are useful not only for the local distribution but also to manage global suppliers since the problems related to protectionism and resource scarcity, sometimes, force companies to search materials also in faraway countries: the mentioned technologies enable to gain efficiency in the transport of goods and in the communication along the chain.

Even though the development of green systems is ongoing, given the related high costs and unclear regulations in this scenario, it is foreseen an improvement of the renewable energy technologies and smart grids solutions to make the SC greener. To achieve the goal of a resource efficient SC other technologies can be used as the abovementioned additive manufacturing and the cloud-based systems (Mai et al. 2016). For example, platforms as a service allow companies to optimize resource sharing and procurements among the different plants in the urban area, supporting also online production, distribution and service scheduling and even the customer in the application of the DIY paradigm. In addition, IoT greatly aids resource efficiency, since it allows for data collection which is useful to avoid excessive inventory and missed production schedules (Parry et al. 2016).

After a disruptive event, like natural disasters, the humanitarian SC has to be immediately activated and technologies like IoT (associated with big data analytics), communication infrastructure, smart wearable devices, and location technologies are useful to save lives during the response phase, facing the first emergency step and quickly tracking people. Moreover, during the reconstruction phase, these technologies can be used to manage in an efficient way the distribution of resources: saving as many costs as possible means being able to help more people.

3.6 Technologies for the Supply Chains of Scenario "ENDANGEr"

Regarded as the most unstable scenario brought forth within scenario-building projections included, "ENDANGEr" shows a collapse of governments in Europe supported by full protectionism and the fragmentation of confederations. Thus, a global trade shift is observed, with power being transferred to emerging market economies. The presence of frugal mass products, risk-hedging production systems, glocal sourcing with local distribution and simple production systems are justified by harsh environmental impacts, boasting resource scarcity and lack of regulations. Hence, resource-efficient SC combined with humanitarian ones are common-place and widely implemented, given the high risk and challenging conditions, especially for companies that must deal with traditional economies being conducted without the presence of intermediaries, enhancing the uncertainty regarding financial resources availability.

This scenario is characterized as the least digitalized, hence it is supported by more traditional SC strategies. Among these, frugal mass products are definitely on the core, partially aided by autonomous and collaborative robots and IoT (mostly through Process Intelligence to support decision making). Given the low demand and high supply risk uncertainty of this scenario, which compels the use of risk-hedging SC strategy, IoT plays a central role through Sensor Technologies.

Sourcing is provided by means of Autonomous Transport Systems, especially Autonomous Vehicles and Drones, despite being implemented on a smaller scale, aimed at supporting the glocal sourcing. On the other hand, distribution is mostly accomplished by Autonomous vehicles for last mile delivery and drones due to the local focus, complemented by Electro Mobility from Alternative Propulsion Systems.

Regarding the low level of digitalisation encountered by companies, production systems will most likely be of simple nature and focused in emerging countries, especially when considering the political shift of power. Likewise, efficient and reconfigurable manufacturing systems are prominent due to the uncertainty surrounding supply, the presence of low variety and large production facilities, as well as timid adoption of autonomous technologies. Therefore, the machine to machine real-time communication and connectivity from Internet of Things, Cyber-Physical Systems implementation and the use of Process Intelligence for decision-making capabilities are considered crucial for the frugal mass products manufacturing capabilities. Moreover, it is expected that Artificial Intelligence will be somewhat prominent, mostly represented through machine learning and deep learning, complimented by Big Data Analytics from Data Science point-of-view.

Sales channels will certainly remain traditional given the economic aspects of the scenario for this SC, hence the need for IoT technologies to rise due to decision-making requirements.

From the sustainability aspect, IoT is present, mostly aimed towards resource-efficient and humanitarian SC through sensor technologies adoption, machine to machine real-time communication and connectivity for information exchange. IoT allows for real-time access to information regarding the position and availability of resources, which is considered crucial in decision-making processes related to natural disasters' occurrences (Prasad et al. 2018).

4 Discussion and Cross-Scenario Comparison

This section focuses on providing a cross-scenario comparison regarding the mapping of enabling technologies. It should be noted that this mapping does not have a quantitative value but aims to provide a qualitative vision of the set of technologies which have been considered for each scenario, according to the technological profile of the scenario itself (digital master, tech fashionista, tech beginner, tech conservative) and its other features (e.g. customisation, sustainability, etc.).

We can expect that SC for "aSPIRANT" and "DiThER" macro-scenarios present all enabling technologies implemented. Nevertheless, it should be noted that "aSPIRANT" scenario presents full implementation of the enabling technologies, due to the presence of a highly digitalized environment, categorized as the Digital Masters one, and availability of investments to support the large-scale implementation.

On the other hand, SC of "DiThER" scenario present the trend for being Tech-Fashionistas, in the sense that the implementation of the enabling technologies is sporadic and less withstanding. Furthermore, the "PrOCEEDINg" scenario can also be considered as Digital Masters, with highly digitalized environment and investments, despite lacking the implementation of Blockchain/Distributed Ledger technology due to the presence of an economic environment with Bank and Fintechs collaboration, which may hinder the development of innovative financial distributed exchange solutions between actors.

Otherwise, SC for scenarios "UNEasE", "ENDANGEr" and "oFFsET", being considered Low-Tech (Tech Conservatives or Tech Beginners, depending on the technologies' implementation level and maturity level), have limited application of enabling technologies due to the digital, economic and sustainability characteristics. For this reason, these scenarios are the ones which will require more efforts in order to fill the gaps in terms of technology development and adoption. In the case of the "ENDANGEr" scenario, the presence of Autonomous Transport Systems, Robotics and AI enables the dynamic development of autonomous technologies. Having a world where the traditional role of banks as economic framework requires the implementation of Blockchain enabling technologies, especially cryptocurrencies such as Bitcoin and Ethereum. Regarding "UNEasE" scenario, Smart Materials are used on the production of Mobile and Wearable Devices applied for customized products (enhancing the responsiveness and reliability aspects), as well as on natural disasters occurrences, tackled by Humanitarian/disaster relief SC.

Lastly, the scenario "oFFsET" presents digital impediment and an innate reluctance to accept autonomous technologies, which hinders the implementation of most enabling technologies. Moreover, the unstable Confederations combined with lacking legislation on all major dimensions more than likely will deter major investments required for research, development and implementation of these enabling technologies. Thus, only enabling technologies which are already broadly implemented are present in the SC for "oFFsET" scenario.

5 Conclusions

This chapter presented the enabling technologies for the SC to be implemented in the future scenarios foreseen for the next decade. The proposed methodology was based on technology mapping and technology portfolio approach, with emphasis on the adoption of Table Management Tool. The enabling technologies were evaluated having the SC scenarios and strategies as the basis for their definition, as well as the technology scouting.

The first results were drawn with regards to the SC scenarios and were detailed on Sect. 3. An overview of the findings was presented in the following Sect. 4. Further, given some overlapping on the possible technological applications in different scenarios, a cross-dimension mapping was carried out, where technologies were grouped for each specific SC strategies concerning 6 dimensions: Products & Services, Sourcing & distribution, SC Configuration, Manufacturing Systems, Sales Channels and Sustainability. This cross-dimension mapping aims at providing valuable inputs for companies and decision-makers that are looking to implement single strategies or bundles with mixed strategies, thus being able to better decide which enabling technologies to focus on to improve their SC performance.

The results of the technology mapping conducted through this chapter, aimed at linking enabling technologies with scenarios and SC strategies, and constitutes valuable input for roadmapping and policy definition. Most technologies can have a declination for each strategy according to the specific aim. Moreover, a technology can be applied to different strategic dimensions and there is the need for an integrated approach to consider technologies not as standalone solutions but in an integrated way.

One relevant aspect turning out from this mapping is indeed the importance of integrating different technologies which is necessary to fully implement innovative strategies for future SC. The mapping in Sect. 4 does not aim to be exhaustive but to give good examples for the wide range of possible applications.

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New Pathways to Future Supply Chains

Paths to Innovation in Supply Chains: The Landscape of Future Research

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Abstract This chapter presents a Strategic Research and Innovation Agenda for supply chain and it is the result of an intensive work jointly performed involving a wide network of stakeholders from discrete manufacturing, process industry and logistics sector to put forward a vision to strengthen European Supply Chains for

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the next decade. The work is based on matching visions from literature and from experts with several iterations between desk research and workshops, focus groups and interviews. The result is a detailed analysis of the supply chain strategies identified as most relevant for the next years and definition of the related research and innovation topics as future developments and steps for the full implementation of the strategies, thus proposing innovative and cutting-edge actions to be implemented based on technological development and organisational change.

Keywords Roadmapping · Foresight · Supply chain strategies · Innovation · Resilience · Digitalisation

1 Introduction

Over the next decade, supply chains (SC)s will operate more and more in an ever-changing environment, shaped by different trends (Kalaitzi et al. 2020) that strongly affect the network configuration and increase the level of uncertainty. In such a complex global context, companies need to tackle the multi-facet challenges (Gürbüz et al. 2020) raised by these trends with the support of new technologies (Stute et al. 2020) and novel SC strategies transforming the way they do business. This renovation requires not only changes in terms of assets and tools for logistics and manufacturing, but also the development of new roles and type of relationships among the actors involved in the network as well as new capabilities and competences. There is therefore the urgent need for companies to adapt the way their SCs are organised and interlinked, by transforming networks into resilient systems that are able to cope with unexpected disturbances. Coordinated actions towards the integration of manufacturing, logistics and process industries are key to strengthen economy and to reinforce the economic system for global challenges.

This chapter presents a roadmap that leads to the definition of a set of 10 SC strategies aimed at supporting industries to face future scenarios (Sardesai et al. 2020), and to the proposal of specific research and innovation paths with a medium and long term perspective, including approaches and models that exploit the potential of new technologies and collaborative mechanisms. The proposed strategies comprise a series of demanding pioneering and cutting-edge actions based on technological and organisational developments. These strategies represent a way of enhancing solid industrial skills, creativity, encouraging research and innovation and therefore they can improve the capacity of the European SCs to add value and to generate employment and wealth. With the full implementation of these strategies, European

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companies should invest in both, tangible (i.e. new enabling technologies) and intangible (i.e. organisational and cultural changes) assets, to face the opportunities arising from the competitive international dynamics. Transformative paths can be defined by implementing and combining one or more of the identified strategies according to the specific long-term objectives, resources and capabilities, thus supporting a continuous strive for success.

The chapter starts with a brief description of the methodology implemented to identify the research and innovation path and the steps to categorize the SC strategies according to innovation along three dimensions. The core of the chapter is from Sect. 4 to Sect. 13 where each strategy is presented including: a description of the context linked to the strategy and its most important features; a list of the main challenges of the strategy, a set of Research and Innovation Topics (RIT)s which are mapped with enabling technologies for the full implementation of the strategy and the expected impact.

2 Methodology

Mapping the future of technological development is a practice adopted by all kinds of organisations (both as single company and as groups of interest and public bodies) to better anticipate new trends and forces, and their impact on different dimensions of their organisations (Boe-Lillegraven and Monterde 2015). Many types and methods for technology foresight have been developed in the last decades (Mishra et al. 2002) and technology roadmapping stands out as the most popular, being widely used to support the definition of research and innovation topics on technologies (Lee et al. 2013).

In this work, roadmapping process was chosen because it is a participatory process, involving experts in a collaborative way (Hussain et al. 2017) aiming at identifying the areas of strategic research and emerging technologies where to invest in the next years. It supports the development of knowledge about the future in the form of private and public policy making.

Therefore, for the definition of a roadmap, it is necessary to face different stages: first, it is important to outline the scope and the boundaries for the technology roadmap; then it is important to engage experts to gather the right information and the third stage comprises an analysis of the results and the data collected to consolidate the information in a more comprehensive way (Phaal and Muller 2009). In this work, taking inspiration from literature (Hussain et al. 2017), five stages have been selected: (1) Consultation with experts; (2) Clusterization of ideas; (3) Proposition of a set of SC strategies for the future; (4) Matching research themes to the SC strategies; (5) Validation.

Figure 1 shows the methodology, described in the following paragraphs, and it highlights the steps done by the project team (white box) and the ones that required the involvement of external experts (ligh blue box). Some steps were performed in parallel during the same period and the results were combined, while other steps

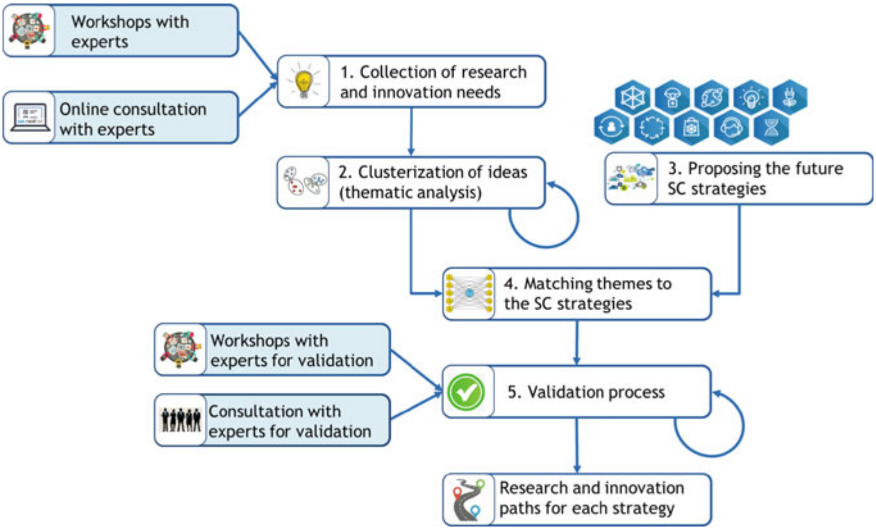

Fig. 1 Methodology steps for SC roadmap

were structered as iterative processes since they required different back and forward interactions bebtween research team and experts in order to arrive to consistent results.

Step 1. Collection of research and innovation needs: experts both from academia and from industry were directly involved through two workshops and a wide consultation with a semi-structured online interview in order to collect ideas, opinions and proposals for the definition of the RITs needed to be addressed to face the SC challenges. The academics and managers invited to participate at the workshops and the online consultation represented different type of: companies (large, SMEs, start-ups), industrial sectors (i.e. automotive, steel, consumer goods, IT, fashion, transportation…), function (CEO, Operation Mangers, SC manager, industrial and academic researcher), role in the SC (i.e. managers from focal company, suppliers, vendors, outsourcers…) and research fields (SC management and configuration, manufacturing, logistics, engineering, risk management, etc.). The two workshops were organised as face-to-face brainstorming sessions in small groups of experts (in world-cafe style) each of them focusing on a particular topic under the guidance of a moderator (Krueger and Casey 2015). The interaction among participants was organised to be open-minded, with undirected atmosphere to facilitate the generation of fast-result insights (Zeng et al. 2019). Each workshop involved a sub-set of the experts according to the specific topics and aim of analysis.

The online consultation has been launched to collect other research and innovation needs based on semi-structured forms. This type of questionnaire allows to go deeper, searching for views and opinions of the interviewee and therefore to explore new paths which were not initially considered (Gray 2004, p. 217). It thus addresses issues and research areas that are important from the view of the involved experts (Kajornboon 2005). The online consultation was structured to identify:

- The most relevant specific challenges for the SCs
- SC dimensions most affected by the challenges (like manufacturing, sustainability, distribution, …)
- Enabling technologies necessary to face the highlighted challenges
- The most relevant research and innovation needs to face those challenges along the chosen SC dimension basing on experts' experience
- The key horizontal issues related to the challenges and influencing the creation of policy recommendations (Zimmerman et al. 2020).

The experts were contacted with a formal letter of invitation where all the aims of the project were explained and timing of their involvement as well. We ended up with 100 experts involved in the period from December 2018 to June 2019.

Step 2. Clusterisation of ideas: thematic analysis is a qualitative research method for identifying, analyzing, organizing, describing, and reporting themes found within the collected data (Braun et al. 2006). This methodology is also useful for handling and summarizing key features of a large data set, helping to produce a clear and organised output (Nowell et al. 2017). This method aims at searching for relevant themes to describe a given phenomenon (Fereday and Muir-Cochrane 2006); this analysis supported the evaluation of 150 forms collected during the workshops and the online consultation.

The thematic analysis is supported by a review of the EU roadmaps, work programs and running projects as a means to compare the results of the consultation with existing research topics identified at European level and to avoid repetitions. These secondary resources complemented and detailed the description of the tools and approaches presented in the RITs.

In order to discover similarities between the data collected and clearly present the results of the consultation, different steps have been followed (adapted from Nowell et al. 2017 and Braun et al. 2019):

- Acquaintance with data: the identification of themes passes through careful reading of the data to familiarise with the content. The ideas were collected according to specific categories which were useful for this step to organize the data and start to separate the research and innovation needs from the horizontal issues.
- Generating initial codes: this allows to simplify and focus on specific characteristics of the data with a short phrase that symbolically assigns a summative and essence-capturing attribute to data (Saldaña 2009). Per each collected form, a short sentence was identified to summarize each specific suggestion.
- Searching for themes and review: when data has been analysed and a list of the different codes identified, it is necessary to sort and collate all the codes to extract the themes. In this step, an inductive approach was used without trying to fit codes and data into pre-existing themes or the researcher's analytic preconceptions. The review is essential to verify if the coded data, belonging to each theme, shape

a coherent pattern and, at the same time, if the themes accurately reflect the meanings which emerge from the data set. For this reason, several iterations are necessary back and forward among the researchers to arrive to a restricted list of research themes that summarize the important issues raised from experts for the identification of the research needs.

Step 3. Proposition of a set of SC strategies for the future: in this step, it is defined how companies should adapt their networks to face those evolutions identified in the research needs and maintain their competitiveness. A dedicated workshop was held with a restricted number of experts from academia analysing the work described in Barros et al. (2020). In fact, the following decisive SC categories were considered (Product & Service, SC Paradigm, Technology Level, Sourcing & Distribution, SC Configuration, Manufacturing Systems, Sales Channels and Sustainability) to map the features of the SCs based on the descriptions of the macro-scenarios. These characteristics were the input for the discussion during the workshop inspiring experts to identify a set of 10 strategies as the most promising to overcome the challenges of the next decade which are:

- Biointelligent Supply Chain
- Closed Loop Supply Chain
- Customer-Driven Supply Chain
- Disaster Relief Supply Chain
- Global Supply Chain
- Human centred Supply Chain
- Hyper-Connected Supply Chain
- Resource Efficient Supply Chain
- Service-Driven Supply Chain
- Urban Supply Chain.

Step 4. Matching research themes to the SC strategies: the results of the step 2 and 3 were matched in order to create a coherent evolution path based on a set of RITs for each SC strategy (Fig. 2). The research themes, generated by the clusterization of forms, have been assigned to the 10 SC strategies based on their main characteristics consequently described in order to define and state the solutions and approaches needed for the full implementation of the strategies, i.e. the RITs.

Step 5. Validation: the RITs per each SC strategy have been defined and a validation workshop with experts was organised with the goal to review the proposing evolution paths. The feedbacks collected helped the refinement of the detailed description of each RITs. In order to reinforce the validation of these results, another iteration was done with a group of experts, who were asked to review the description of the strategies and the related RITs.

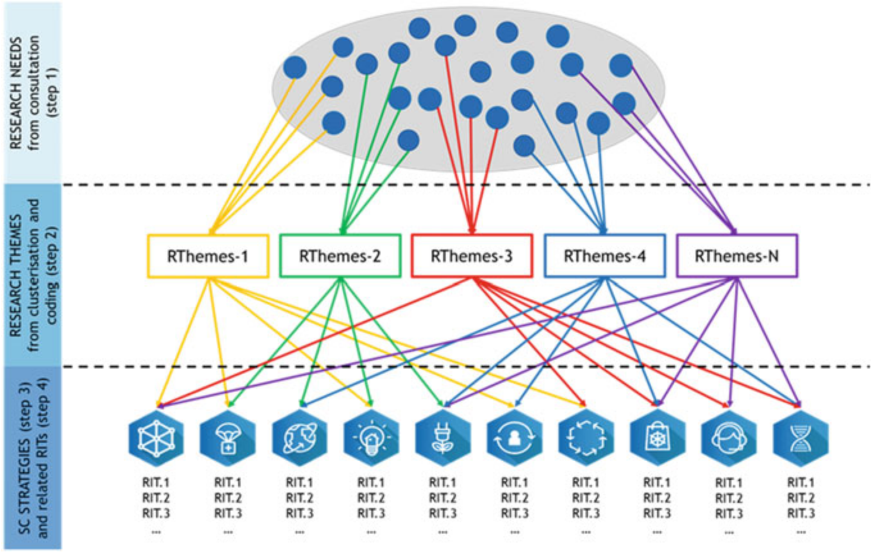

Fig. 2 Matching research themes to the SC strategies

3 Innovation in Supply Chain Strategies

According to Arlbjørn et al. (2011, p. 8) "SC innovation is a change (incremental or radical) within a SC network, in SC technologies, or in SC process (or a combination of these) in order to enhance new value creation for the stakeholders." The focus on these three dimensions allows to create a path to innovation (Christiansen 2000; Mandal and Scholar 2011) as a way to gain sustainable competitive advantage relying on the competencies of many different firms within their SC network (Franks 2000; Arlbjørn and Paulraj 2013).

Other contributions available to date do not approach the concept of SC innovation from a holistic point of view and focus on investigating separately some sectors, such as for example the logistics one (Zijm et al. 2015; Lin 2008) or addressing specific issues as sustainability (Tebaldi et al. 2018), while some recent works focus on investigating the implications of I4.0 on SC management (Kagermann 2015; Hahn 2020).

In this work, the definition of innovation paths in SC was based on analysing how some specific dimensions like processes, technologies and network structure are affected taking into consideration the need of a radical change in these areas. For this reason, taking inspiration from the model proposed by Arlbjorn (2011), we define three categories where to apply innovation paths:

- Business Processes: a set of business processes have been identified and considered as object of innovation for SC: Product & Service design, Sourcing & Distribution, SC Configuration, Manufacturing Systems, Sale Channels. It is expected to have SC strategies where it is necessary to fully implement new practices and activities in specific dedicated processes with support of innovation, where it can be necessary to change the practices in some of them, or where it is necessary to fully revise well established processes.

- Technologies: this category is related to the implementation of new technologies for SCs to increase collaboration, facilitate information exchange, as well as visibility within the network (Arlbjørn and Paulraj 2013). Given our innovation-driven approach, technological changes can be considered a baseline for all the SC strategies.
- Network: it focuses on the structural aspect of the SC and how it is organised. It concerns the position of a company in the SC (i.e., distance from the end consumer) and horizontal and vertical aspects (collaboration mechanisms, partnerships, etc.). Moreover, it is related to the levels of resources used to integrate as well as manage intra- and inter-organisational processes of the SC members (Arlbjørn et al. 2011).

Given these dimensions of analysis (business processes, technologies, network) and the related degree of innovation and maturity, the following categories for the SC strategies have been proposed:

1. *Trend setting SC strategies*: this category includes novel and highly innovative strategies which are not yet applied in a wide spread manner. The implementation of these strategies implies radical changes at process, network and technological level.
2. *Advancing SC strategies*: strategies in this category are already applied but only partially spread and implemented in industry. The full implementation of these SC strategies is yet to come, because only some SC processes are on the "direction" of the strategy but not all of them have been changed or innovated. The full implementation of these SC strategies implies incremental changes at process level and radical changes at technological and network level.
3. *Revamping SC strategies*: in this category, well-established strategies are considered, and they can make a step ahead in innovation by the adoption of new digital technologies. All processes of these strategies are consolidated and well known but they can highly benefit from innovation. They imply incremental changes at process and network level and radical at technological level.

The 10 SC strategies, identified and characterised through the matching with the research themes as described in the steps of the methodology (Sect. 2), will be assigned to each of the 3 categories based on their level of innovation.

In the following sections, each SC strategy is outlined with reference to its specific challenges. The related set of RITs, derived from the technology roadmapping, are described as a way for the full implementation of innovation in the SC strategy, and the expected impacts are also reported.

4 Biointelligent Supply Chain Strategy

In recent years, research in logistics has started using the phenomena of nature as a basis for creating innovative solutions and methodologies. Increasing amounts of various logistic research topics apply principles of behavioural biology, thus benefitting from the principle of nature (Tinello et al. 2017). This integrates e.g. swarm intelligence that, by now, sets the bar for several algorithms in autonomous applications. The latest research refers to Biointelligent Supply Chains (BIOSC), with a focus on mirroring nature to derive further systemic solutions and technical (digital) systems (Bio-Based Industry Consortium-Sira 2017). Future research depends greatly on interdisciplinary working groups including researchers and experts from biotechnology and engineering to SC and informatics (Fraunhofer 2019). This enables new SC structures that integrate bio-hybrid production technologies. The BIOSC strategy requires parallel concept developments of circular economy, bio-based production and digital transformation. While the latter falls short of creating a process on the way to a sustainable economy, the concepts of circular economy omit essential aspects of manufacturing industry and society (ManuFUTURE 2018). Thus, while bio-based production creates the basis, the combination of digitalisation and circular economy empower a sustainable, biointelligent economy. The aims of a BIOSC are twofold. Firstly, it follows an ecological goal in which production processes avoid harmful material and green concepts enable emission neutral SC processes. Secondly, BIOSC pursues an efficiency goal by imitating concepts from nature such as decentralised control, self-organisation and self-configuration. Biointelligent principles and systems employ nature identical and nature-analogue processes and technologies to improve production and communication for an efficient value creation along the network that should be able to restructure autonomously its configuration to achieve resilience. The aim is to design products and services to be sustainable, not to harm the ecosystem and to build an (self-)adaptable SC around those products and services. As such, biointelligent transformation is an interdependent science. It is driven by progress in various fields of science such as bio-, information and production technology.

4.1 Specific Challenges for BIOSC

A set of specific challenges related to the features of this strategy is here reported representing the gaps to be covered with innovative approaches and tools as from the RITs in the following section.

1. *Technology Maturity*: along with the BIOSC, changes within the production processes are required, like tissue engineering and 3-D-printing. New concepts need to be developed to enhance the efficient reuse of resources. This development will progress stepwise according to the value creation by Imitation, Cooperation and Assimilation. In terms of technology, this includes production technologies to

separate materials and create smart materials, e.g. based on further nano-material production flexibilities.

2. *Collaboration in a decentralised environment*: a BIOSC integrates several highly interconnected decentralised units. This includes new actors like prosumer and companies for disaggregation or amendment of products. In this decentralised environment, good collaboration mechanisms as well as new and highly adaptable organisational settings are required.
3. *Organisational Settings*: new organisational settings evolve along with BIOSC and the increasing amount of decentralised production units. Organisational structures have to adapt and to find parallels in nature.
4. *Flexible responsive SC availability*: request for production-on-demand requires a highly flexible and responsive SC. Autonomous vehicles and production units have to react flexibly to changes. The flexibility integrates a strong collaboration between SC entities to cover upcoming disturbances and to satisfy highly customised products.
5. *Resource Management in a BIOSC*: based on the concept of circular economy and the BIOSC paradigm of 100% resource efficiency, new concepts for resource management are required. This includes knowledge about availability of resources and new transportation strategies for a flexible integration of changing SC partners. New technologies and methodologies are required to enable industrial symbiosis for sharing, including sharing between small decentral units.
6. *Personalised shipments*: the idea of the DIY community and prosumers creates a high amount of personalised shipments. New ways of efficient and sustainable transportation have to be developed, including possibilities with biological assimilation and adaption of SC processes. Furthermore, an integration of autonomous vehicles along the SC needs to be implemented to incorporate and connect small decentralised units.
7. *Technological Integration for seamless connections*: to enable real-time communication, a respective interoperability for mobile devices and IoT systems, as well as communication between autonomous devices, need to be put in place. This includes the integration of heterogeneous devices and applications. Respective IT architectures are required to fulfil the interoperability and to enable a reliable stream of the increasing data flow.

4.2 Research and Innovation Topics for BIOSC

The most important research and innovation topics for the BIOSC strategy are here described.

<u>RIT.1: Organisational change towards a new taxonomy for biointelligent SCs</u>

Decentralised units like self-acting autonomous transport vehicles, plants or prosumers characterise BIOSCs. Along with those decentral, autonomous and ad hoc acting entities, the roles of each actor change. The perspective of a focal company within a SC setting diverts towards a highly interconnected network of autonomously acting units, taking into consideration the multiple interfaces towards producer, customer or prosumer. Within the BIOSC, several changes are expected at production and SC level too. To guide those changes, a new and common organisational structure based on a taxonomy for BIOSCs needs to be established. Those organisational structures shall be inspired by biological settings. New matrix structures can be combined with Shared Leadership, in other cases cellular organisation or swarm organisation might be useful. As different organisational settings can apply and might get combined, the biointelligent SC requires a structural approach towards the setup of a network integrating the concept of prosumer. A new taxonomy for SCs shall support these upcoming changes and propose a way forward on how and in which way strategic goals need to be set. This work forms the basis for several organisational processes as self –organisation between decentral units. As biologists have formed their taxonomy way back, it thus can provide a primary guideline for an interdisciplinary taxonomy for BIOSCs. In this context, the model of layers systematically divides the different levels of networks, SC and production to find biological equivalents. Starting from a protozoon, logistic functional areas or systems and biological structures are compared with each other. This aims at investigating the possibilities of transferring bioequivalent processes (ten Hompel et al. 2019).

RIT.2: Nature inspired symbiotic SC models

Within this research topic, nature inspired analogies shall motivate the set-up of SCs. This requires new bio-inspired concepts to identify possibilities of increasing efficiency, to locate raw material streams and to estimate their availability. While symbiotic SC models follow the principle of lowest resistance, the concept of BIOSC builds upon a symbiosis with nature. The development towards the proposed BIOSC can be segregated best into three differently timed phases towards 'Imitation and Cooperation with Nature'. Each phase creates a part towards a BIOSC—while imitation stands for value creation by creating an image of nature, cooperation combines biotechnology with SC structures or other forms of natural symbiosis. Imitation creates hence bio-inspired management and bio-inspired organisational settings, while cooperation stands for changing processes along with the integration of bio-based resources and bio-based materials. In the first step, the transformation includes learning from the results of nature, e.g. using sensor data for real-time decision for triggering different SC routes (see SOFiA project 2018). It implies learning from the process of evolution and from the principles of nature, e.g. in a self-organising transport model using bio-analogue optimisation methods. Conceptually, it includes the necessity for autonomous capacity and demand matching methodologies. A second phase includes imitation and cooperation and can comprise cargo ships that recoup energy through tidal forces along their journey. This symbiosis can imply material and transportation flows that are coordinated by weather (e.g. sea freight is favourable in windy weather and appropriate current). Autonomous vehicles might become independent, decentralised units that require maintenance only and their coordination become more flexible. The third phase then, involves a complex interplay of entities exchanging material and information from different sources and an adaptation of various, continuously changing SC partners. The SC consists of several decentral organised nodes within a regional area. Transport is characterised by short distances and sharing. Predictive planning supports self-structuring of the SC which can change and adjust to respective circumstances similar to a body system that reacts to physical activities. Self-organizing entities motivate their planning on the overall strategic goals of a company network. Along with the changes towards biointelligent production, a new conceptual framework for SCs is required in order to enable biointelligent SCs along the following dimensions:

1. Identifying concepts and possibilities of imitation of nature within the SC to increase efficiency.
2. Supported and inspired by the biological taxonomy, it needs to identify possibilities to realize symbioses between nature and SC. This shall lead to the development or extension of a biointelligent taxonomy for SC.
3. Identify concepts for the assimilation phase dealing with conceptual strategies for the organisation of decentralised nodes.

<u>RIT.3: Ecosystem for biointelligent SC</u>

In nature, SCs establish themselves via a natural bond. In a similar approach, BIOSCs and networks need to be formed. The integration of DIY partners, the concept of prosumer and the idea that each entity is consumer as well as provider of resources, results in the effect that suppliers of raw materials evolve and regress in a continuous flow. Only a highly interconnected system can ensure that new partners can be connected. A new ecosystem is required to enable a quick adaptation to new circumstances. New concepts to enable a self-structuring of SCs along with AI technologies have to be established. These concepts need to integrate not only the locating of suppliers but also the circular economy aspects to determine possible use for recycling or disaggregation of a product to reach a bio-inspired organisation. Moreover, high flexibility and quick adaptation of new ecosystems offer a great potential for the development of new business models. Continuous joining and quitting of players as well as the integration of DIY partners lead to flexible and self-structuring SC networks and to new platforms for connecting all stakeholders. The customer takes on the role of an associate producer leading to highly individualised, agile products and services. Furthermore, revenue models are continuously adapted and new (ecologically oriented) payment and pricing models arise, inevitably leading to new business models. To support these developments, a BIOSC with its decentral decision units requires different IT architectures to ensure a constant data availability with low energy demand. Next to a data exchange in real-time, effective methods for combination of data and its visualisation are required. An important aspect in this regard is short latency. Again, the concept of imitation of and cooperation with nature need to be adapted. New concepts for IT Architecture have to be established to provide immediate access to relevant data and ensure data availability between decentralised production units.

<u>RIT.4: New SC processes to realise biointelligent SC paradigms</u>

Along with the paradigms of BIOSCs, processes have to change accordingly. New production technologies allow for a production whenever needed. A production on demand implies material to be at hand whenever required and, therefore, it is necessary to use regional or local sources. In addition, the influence of a DIY community and the prosumer integrates several small players such as material and component suppliers or users that require re-designing processes within a BIOSC. Moreover, the advances in circular economy ensure a re-utilisation of materials. Thus, reverse logistics processes become equal to material supply processes. A new set of actors responsible for disassembling and renewal, separation and refining products, as well as other players overseeing collection and preparation are included. SC processes change, bringing with them re-utilisation and re-structuring of products and auxiliary (transport) material. This setting requires a structure of very flexible and scalable production units. Its flexibility reflects on the SC processes as raw material suppliers and related component suppliers can change on an ad hoc basis. This entails that a SC structure is not fixed but has to be agile and adapt flexibly to the requested demand and product type and find a suitable set of suppliers. With regard to the use of outputs of other production processes, the supply might need to be sourced from several entities. Further research is required in terms of new distribution systems (e.g. integration of autonomous vehicles, and integration of IoT devices or further innovation for supply mechanisms), energy and communication infrastructure (necessary to support the SC process and financial payments settings), and innovative transport systems.

RIT.5: Coordination and decision making within biointelligent SCs

Based on the concept of prosumer and the re-utilisation of any kind of output in a production process, each entity in a SC serves several customers. This evolves into a highly interconnected network of different SCs, that serve a different strategy. Accordingly, the goal within this research topic is twofold. First, concepts in nature have to be identified on how and if a common strategy for all networks exists or indeed if an external strategy has to be provided externally to achieve a bio-inspired management mechanism. Secondly, the coordination between entities and respective decision making on SC and production level has to be adapted according to bio-inspired processes. Future research has to provide concepts for decision-making, e.g. for contract negotiation, communication of capacity availability and raw material provision to allow for bio-inspired management. Each player in the production unit openly communicates its availability of resources in real-time to find additional customers. Disruptions and disturbances within a SC, like breakdowns or volcanic eruptions, trigger immediate changes of routes and suppliers on an autonomous basis. Coordination systems between autonomous entities need to have information about location of the incident and products loaded. Those examples show that new, nature based communication systems are required for the coordination within BIOSCs chains. In terms of data storage, the transfer of small packages is required. A first approach is provided by edge computing. In contrast to cloud computing, edge computing refers to decentralised data processing at the edge of a network. Data streams are processed at least partially on site (e.g. directly at the end device or on the equipment) in a resource conserving manner, but still benefit from the advantages of the cloud. Smart ecosystems support the use and reutilisation of resources—the breaking of former isolated solutions for the control of business processes and technical processes, instead forming a unified system. The flexible production environment requires traceability for raw and intermediate materials and new sharing concepts for data. Moreover, the support of connected and autonomous cars and its integration into decision making create data flows that need to be handled. Decentralised units need to be organised on a real time basis. IT Architectures, hence, have to ensure a common domain specific language and integrate new sharing concepts. Aspects of redundancy need to be considered to safeguard relevant sets of data.

4.3 Impact

The innovation path identified with the RITs can have significant impacts on SC performance. The future impacts expected from the development of the RITs for the BIOSC strategy include:

- Increase of efficiency as an overall achievement of BIOSCs
- Increase in sustainability by ecological product life cycle management
- Increase of agility via decentralised and flexible production and transport units
- Increase in responsiveness via flexible matrix structures and open capacity communication
- Increase of reliability due to improved communication processes and common understanding
- Increase of transparency via common taxonomy.

5 Closed Loop Supply Chain Strategy

Closed-Loop Supply Chains (CLSC) are networks that "include the returns processes; the manufacturer has the intention of capturing additional value and further integrating all SC activities" (Guide et al. 2003) taking back products and re-using materials or components (ALICE 2014). CLSC is strictly interconnected with circular economy, with productive systems simultaneously considering forward and reverse SC operations, starting from product design up to operational processes (Lacy and Rutqvist 2016; Webster 2015). The recycling industry, with more than 2 million informal waste pickers, is now a global business with international markets and extensive supply and transportation networks, but the potential still has to be fully exploited. As an example, in 2016 the world generated 44.7 million metric tonnes (Mt) of WEEE (Waste Electrical and Electronic Equipment), yet a mere 20% was recycled through appropriate channels (Baldé et al. 2017). Different strategies can be implemented for the management of the resources loops as proposed in Bocken et al. (2016): (i) Slowing resource loops: through the design of long-life goods and product-life extension (i.e. service loops to extend a product's life, for instance through repair, remanufacturing); and (ii) Closing resource loops: through recycling, the loop between post-use and production is closed, resulting in a circular flow of resources. CLSCs include traditional forward SC activities as well as the additional activities of the reverse SC and the reintroduction to the market (Guide et al. 2003): (i) product acquisition from end-users; (ii) reverse logistics to move the products from the points of use to a point(s) of disposition, (iii) testing, sorting, and disposition to determine the product's condition and the most economically attractive reuse option, (iv) refurbishing to enable the most economically attractive of the options: direct reuse, repair, remanufacture, recycle, or disposal, and (v) remarketing to create and exploit markets for refurbished goods and distribute them.

5.1 Specific Challenges for CLSC

A set of specific challenges related to the features of this strategy is here reported representing the gaps to be covered with innovative approaches and tools as from the RITs in the following section.

1. *Strong collaboration along the closed chain*: mission business models to help manufacturers, shippers, logistic providers and users to achieve common sustainability objectives, to obtain cascading of value streams within CLSCs, to eliminate waste by designing decoupling resource use from value adding (Product-Service-Systems, Sharing etc.).
2. *Efficient resource management in return process*: capturing additional value for the return processes makes it necessary to design a more efficient (and holistic) manufacturing, collection, recovery, disposal, recycle, and reuse in all stages of the SC. Quality assurance is an important element for goods produced with recycled materials and requires transparency of materials used throughout the SC. Uncertainty of the return in terms of quantity, quality and lead time, as well as pricing, are also key challenges in CLSCs.
3. *Secure and reliable information management in industrial symbiosis*: quality of information and use of suitable channels to share information are two key elements along the SC, especially when industrial symbiosis is considered and sensitive information sharing is required to encourage companies to collaborate and join networks.
4. *Rethink regulation for Circular Economy processes*: the definition of new business models makes it necessary to rethink regulations and incentives for businesses to repair, disassemble and remanufacture products and therefore support the circular economy (Govindan and Hasanagic 2018). Take-back regulations, aimed to make manufacturers physically and financially responsible for acquiring and disposing of the used products in an environmentally friendly manner, should also be implemented.

5. *Technology development for reverse logistics, waste management and recycling, reusing and remanufacturing*: further developments of existing technologies for efficient upstreaming management of materials along the SC are needed, e.g. AI image recognition for sorting and evaluation, robotics and biotech for separation of waste. Development of existing recycling technologies further to make their input more predictable to allow better SC planning is also essential.
6. *Lack of shared KPIs for the sustainability assessment*: there is the lack of a shared criteria to evaluate the sustainability along the whole network and this makes difficult to determine who are the more sustainable actors and the impact on the environment of the SC. Criteria such as generation of solid or chemical waste, air emission, water waste disposal, other recovery options and return disposition have to be considered.

5.2 Research and Innovation Topics for CLSC

The most important research and innovation topics for the CLSC strategy are here described.

RIT.1: Reverse logistics for recycling, reusing, remanufacturing in circular economy

Product returns in CLSCs represent a value stream, not just a waste stream and logistics is a key enabler to ensure sustainability of circular economy by providing smart and sustainable networks and services. This requires research activities related to the development of new business models, including bundled services, after-market and reverse SC, addressed with an integral approach not only in the geographical sense (urban versus rural and combined) but also for the end-to-end SC processes addressing scarce resources management. New business models and the implementation of large pilot cases should demonstrate a substantial increase of supply network efficiency and sustainability of direct and reverse flows management that are currently operated separately, but could be integrated seamlessly. To assure integration, further development and the application of technologies such as IoT and platforms will help networks to monitor goods and the information coming from the reverse flows. The use of autonomous systems and the development of big data analytics will optimise the collection of products at the end of their life integrating the forward and reverse flows. Moreover, an increasing use of smart materials and sensors will enable data collection on product usage. New tools should be developed to analyse these data and propose the best solution for recycling/ reusing/ remanufacturing goods according to the specific condition of products. Research advance is also needed to develop new sensors to identify/trace and analyse product composition. Robots and additive manufacturing technologies should ensure the efficient transformation of returning goods in valuable products for the network and external actors.

RIT.2: Industrial symbiosis and other mechanisms for collaborative SC

In order to implement closed-loop schemes, research needs to explore new mechanisms for collaboration and coordination along the SC as follows:

- Industrial symbiosis expands the existing basis of SC partnerships since it is "a form of collaborative supply chain management aiming to make industry more sustainable and achieve collective benefits based on utilisation of waste, by-products (Herczeg et al. 2018). Research should be dedicated to support companies in defining new models to reduce landfill and to transform and re-use as much waste as possible so as to close the loop and improve the use of secondary raw materials, developing new relations and business models. New ways for energy storage and usage need to be implemented, taking into consideration new demand-response approaches and sharing mechanisms. New models to share other resources like heating and water should also be developed involving not only industrial companies but also public authorities and civil society with an integrated approach; this will create an ecosystem in which environmental and business goals are combined and all the SC partners have their own responsibilities to reach sustainability.
- New methods and tools for systemic eco-innovation approach in society towards sustainability and sharing models. Technologies such as IoT, data science and cloud-based computer systems shall be used for sharing information and resources along the SC also during the design phase, to make sustainable products to be easily recycled or remanufactured (Govindan and Hasanagic 2018) and also based on recycled materials. Eco-design is fundamental in helping companies find new solutions for the through-life management and end-of-life of products and equipment. In this sense, new tools based on collaborative platforms shall be developed to support the co-design of products in a networked environment that comply with a "make it easier to repair" approach.
- Supplier relationship management models. The increase of reused materials in the SCs has an impact on the supplier selection strategy and portfolio. It is necessary to design the structure of SC and the relationship in a more efficient and smooth way considering the trade-off between cost-efficent and environmentally friendly objectives. Research shall focus on the optimisation of the procurement infrastructure and manufacturing process, including design and development of packaging, source-to-pay, organisation and supporting IT systems.
- Customer relationship management models. new models to allow customers to receive data as a service will have to be explored to increase their awareness towards environmental and social issues. Technologies to be used to properly collect and provide added value for these data include IoT, data science, and cloud-based computer systems.

RIT.3: Digitalisation supporting closed-loop SC

Data driven SCs are characterised by full connection, integration and readiness to analyse big data. Further research is needed towards the creation of multi-actor open platforms to assure the management of the flow of information and coordinate goods and waste and related recycling processes, optimising the matching between supply and demand in the secondary raw materials market. Technologies such as IoT, data science, cloud-based computer systems, and artificial intelligence can be applied to take advantage of the use of massive and meaningful data to identify new opportunities for collaboration. Thus, research should focus on:

- Innovative managing systems: systems communication, decisions and accountability for integration of different factories, automated and distribution systems involved in recycling, reusing and remanufacturing processes.
- Integration of existing technologies and development of communication standard for horizontal integration in take back schemes and reusing processes. Establishing communication standards, practices, techniques, cost-effective, efficient means, as foundations of collaborative models for recycling processes. Foster the development and adoption of communication standards for easy data and information transfer.
- Integration of technologies and actors along the SC to understand its real time status and waste streams. Integration of edge computing in SC processes of data analysis to receive real-time data of the waste collection points.
- Integration of online marketing with operations and logistics via a digital platform to facilitate communication and information between suppliers and customers to create awareness on SC practices as a way of enhancing customer attitude towards sustainability.
- Ensuring interoperability between the various platforms used by different actors (from customers to suppliers), e.g. platforms with various waste nature (electronics, chemistry, etc.).

RIT.4: Optimisation of waste management operations

A more efficient (and holistic) design of manufacturing operations, including collection, recovery, disposal, recycling, and reuse of civil and industrial waste supported by the use of advanced automation technologies, will increase added value in the return processes of CLSCs. Research in the above-mentioned stages should include:

- Demonstrators of hub operations, transport, packaging systems, containerisation, handling technologies management, monitoring and tracing of resources throughout supply cycles for direct and reverse flows integration.
- Definition of innovative models to map relationships within and across sectorial SCs, based on identification of waste and by-product flows, barriers and opportunities for synergies in the circular economy paradigm.
- Re-design and re-planning materials, packaging, lot size, etc. using waste materials according to the specific properties and behaviour of the material itself.
- Circularity of goods and energy flows in order to achieve self-sustained triple bottom line SCs (or value co-creation in networks). Waste management from companies-symbiotic networks, including the traceability of waste flows and interoperability in circular economy.
- Zero defect production processes to eliminate waste. Studies on how to use additive manufacturing for this objective can also help. New economic frameworks to remodel/reorganize the SC in order to decrease the CO_2 footprint for SC and/ or neutralize CO_2 emissions.

Technologies for efficient upstreaming of materials along the SC are also needed. Automated and smart tools for sustainability should be developed to:

- Shorten the distribution network through B2C technologies for sustainable reverse logistics.
- Develop a new paradigm and rules of interaction among SC actors to fully integrate waste management flows and operations.
- Implement and adopt total cost of ownership models for new waste transportation and tracking systems.

RIT.5: Standardization of methodologies and KPIs for assessing sustainability

A diffuse increase of consciousness towards environmental issues from consumers and civil society influences the way SC activities are held. Thus, firms will have to offer environmental friendly solutions as well as demonstrate being responsible from a sustainability perspective. It will be importance to establish SC contexts consistent with the circular economy paradigm, which associate the supply and demand to improve resource efficiency. Therefore, companies need to be able to properly "assess and measure" the environmental and social sustainability level of their operations. Apart from a growing number of standards and initiatives related to sustainability, innovative and holistic measurement systems for sustainability assessment within CLSCs still have to be developed. In particular, research should be focused on:

- Defining a measurable set of indices for sustainability of SC. These can be used as a decision parameter to benchmark the sustainable development in all stages of the SC. Special emphasis should be placed on closed-loop indicators.
- Finding new ways to "certify/guarantee" sustainability of companies through evolved LCA techniques. It is necessary to make consumers aware of sustainable and socially responsible SC practices adopted by firms and understand how much more they would be willing to pay for this information.
- Using of blockchain as an enabler for the transparency and traceability along with networks, and sensor technologies to manage product information.
- Standardisation of the different methodologies and models to assess and measure the sustainability in supply cycles considering both production and logistic performance.

5.3 Impact

The innovation path identified with the RITs can have significant impacts on SC performance. The future impacts expected from the development of the RITs for the CLSC strategy include:

- Reduction of logistics costs thanks to opportunities of synergic flows
- Reduction of Processing time (collection, sorting…) of products and waste
- Decrease of material consumption
- Increase of Energy efficiency

- Reduction of CO_2 emissions
- Increase of use of recycled and recyclable materials.

6 Customer Driven Supply Chain Strategy

The role of the consumer has been undergoing rapid changes over recent years, with an increase in the number of informed, educated, up to date consumers, in a market with a choice of products wider than ever. Social media and enterprise mobility together enable new consumption patterns also leveraged by trends, such as the middle-class explosion and the rise of individualism and personalisation. The increase in the number of middle class accounts for 64% of total consumerism, worth over $9.5 trillion (SGE 2015). Currently the middle class population spends $35 trillion annually and forecasts indicate they will spend $29 trillion more by 2030, constituting for roughly a third of projected GDP growth (in terms of purchasing power parity) (Kharas 2017). In addition, individualism emerged as a social trend demanding for a totally different customer relationship and shopping experience, offering higher level of customisation (Nielsen 2016; PwC 2017; Martinelli and Tunisini 2019). Customer expectations are on the up, and with it, a more tailored experience, and 36% of customers are interested in personalised products or services (Deloitte 2015). New production technologies such as 3D printing enable customisation and personalisation of products across multiple sectors (Ryan et al. 2017). Customers are also more willing to buy local products. Moreover, the DIY paradigm enables and encourages them to design, make or assemble products themselves. Consumers are increasingly concerned about their privacy too, and consumer protection in the digital single market became a key priority in Europe. The value of European citizens' personal data may approach 1 trillion Euro annually by 2021 (EU 2018). Legislation on intellectual property rights (IPR) is another relevant topic affecting this strategy: eight out of ten companies that exchange data with other firms do it with their customers (83%), mainly due to their increasing involvement in product development (PwC 2018). Finally, customers prefer sustainable companies: corporate social responsibility disclosure has increased dramatically (KPMG 2017). Decision along the SC need to be driven by customer's needs, expressing their own singularity in terms of products and services. The customer should be integrated not only as a source of capabilities but also as a co-creator developing collaboration, as it is necessary for aligning the SC from downstream to upstream by leveraging inter- and intra-organisational interactive relationships (Martinelli and Tunisini 2019). Customer driven strategies mainly rely on the agility concept, which aims for demand and production alignment, fast production and delivery of products in response to changes in customer demand (Lyons et al. 2012; Medini et al. 2019).

6.1 Specific Challenges for CDSC

A set of specific challenges related to the features of this strategy is here reported, representing the gaps to be covered with innovative approaches and tools as from the RITs in the following section.

1. *Collaboration and Orchestration to meet customer needs*: the development of new mechanisms to enable coordination and synchronisation among all the actors of the chain to meet customer needs is required, complying with the goal of matching supply and demand and creating agile/responsive SCs.
2. *Leaner and flexible responsible SCs*: customer driven manufacturing drives a make to order (MTO) production system. This type of SC demands more intelligence and optimisation to guarantee business profitability. A flexible responsive SC through proactive procurement, JIT delivery/replenishment, and on-demand forecasting is needed.
3. *Personalised shipping drives changes in the SC*: personalised shipping increases cost of delivery/ pickup due to the increased complexity of achieving specific customers' delivery in time and quality manner. In addition, smart management of added packaging complexity is needed, e.g. size, package, confidential information, lack of bundling opportunities).
4. *Matching custom demand*: as each customer is different, understanding customer demand is important. In this sense, the development of new models and tools for gathering and handling huge volumes of data from customers is needed. Data privacy should be taken into consideration too especially when there are several actors involved.
5. *Developing new business models*: collaborative B2B technologies are fundamental because companies have to rapidly respond to their customers' needs while outsourcing their supply source globally (Asare et al. 2016). Explore standardization and data homogeneity along business and markets, creating open protocols and reference models (B2B, B2C and B2i) is also important.
6. *Assuring SC traceability for customer trust*: beside the alarming economic impact, when fake products enter the market, consumer safety is jeopardised, and people lose confidence in the brands they trust.
7. *Guaranteeing protected IPR*: the increased involvement of customer and supplier concerned with the development of customisation and personalisation practices and the consequent data exchange requires properly handling IRP related issues.

6.2 Research and Innovation Topics for CDSC

The most important research and innovation topics for the CDSC strategy are here described.

RIT.1: New models and tools to understand customer needs

With the explosion in product variety and increasingly sophisticated customer needs, demand forecasting is more and more difficult. The development of new models and tools for gathering and handling a huge volume of data from customers through data science and AI represents therefore a relevant research issue. The adoption of new tools and methods for demand sensing, which will probably need to incorporate more AI and big data techniques in addition to standard forecasting methods, is essential. Models to better segment the market and novel revenue management practices will have to be explored in order to help firms in facing more diverse customer bases due to the increased product variety. Being able to charge the right price to a particular customer based on the product/service offered is not an easy task. Therefore, understanding consumer shopping behaviour, retrieving data from social media and wearable devices (using big data, machine learning, cloud computing) and how much they would be willing to pay for personalised goods is critical. Research advancements on Data Science and IoT has particular relevance, increasing the capability of learning requirements of customer preferences, habits and values, making it easier to tailor and to segment the SC to make it more efficient. Getting closer to consumers to know more about "local tastes", understanding what drives them to ask for certain goods, to provide better service (e.g. after sales services, management of returns) is an additional crucial topic.

RIT.2: New technologies and SC models enabling personalised production

In CDSC, firms offer a wider variety of personalised products, which complicates both the product design and production processes in a distributed model. The following research issues should be addressed:

- New solutions for assuring seamless integration with product design (including the design of the final product and the input materials used in production, which requires efficient communication and coordination between second tier suppliers). Research advancements in Data science and cloud based computer systems are essential in order to develop customer data platforms (CDPs) build on first-hand data, a persistent customer base, and highly connected with current data management platforms.
- New solutions for product development and acquisition of the customer requirements together with innovative product configurators also based on VR/AR technologies, advanced measuring and configuration systems, and platforms for product monitoring.
- The development of innovative technologies for the realisation of customised products (small and lot 1 batch sizes) including smart and functionalised materials, additive manufacturing and continuous processing (e.g., 3D printing), micro-manufacturing, hybrid processes. Regarding the increased importance of DIY or prosumers, it is necessary to provide the consumers with new technology/platforms enabling their involvement in the process (also in the production process), and providing central support services (e.g., sourcing of raw materials, distributing to end consumers, collect returned goods, financial transactions when purchases occur between different entities).

- Solving IP right issues if customers are heavily involved with the "design" of the product (design right standardisation, registered designs and copyright) through advanced distributed ledger and blockchain technologies.

Furthermore, new models to allow companies to get closer to the final customers delegating customisation activities to local factories, or to customer location will have to be investigated. Future research on technologies to be able to produce in smaller facilities and new SC production/sourcing/ distribution models for this decentralised setup becomes more important. For this, containerised mobile plants, fablabs, hotspots and service centers shall be established.

RIT.3: New models and tools for dynamic Customer-Driven SC

An agile network is essential to respond to customer demand and deal with a wide variety of products, variability and personalised offer. It is thus necessary to do research on the development of innovation management systems for decentralised production models where manufacturing capabilities are spread in different facilities. This in turn, brings about the need to define new logistic systems where digitalisation can support the tracking and provision of raw materials and components, as well as supporting maintenance and remote usage of machines in real time. Solutions for automatic transformation of customer choice in SC operations shall be implemented to enable a seamless flow of information from the collection of customer requirement to its transformation in production and delivery orders. The SC has to be dynamic and automatic network configuration systems have to be explored and developed in order to enable the activation of specific SC actors, according to actual customer needs. New models and tools should be based on advances in big data analytics to increase the capacity of companies to manage large quantities of data from a variety of sources (client, suppliers, machines, and social media) and also on AI to support the selection and management of supply and distribution networks, based on real-time exchange of information between the actors involved. The use of big data along the SC supports the retrieval of customer information and the seamless transformation of customer needs for orders. The results of trends analysis from social media that support the definition of products variants and collections will have to be accessible for all SC actors and provide the customer with information and suggestions, developing an appropriate communication infrastructure. Moreover, big data can be used to activate new distributed ledger processes or similar technologies, ensuring that transferred data are original, and to conceive smart contracts for regulating different processes (from design, to production, to logistics). Tools to be developed further include the exchange of point of sales data, AI based collaborative planning coupled with forecasts, forecast replenishment, and a cross-platform data-exchange system able to facilitate the formulation of CDSC relationships. Research shall concentrate also on the development of new tools and approaches to support the definition of ad hoc SCs that need to be set time by time according to the needs of the customers, or based on agreements among themselves willing to set up new business (sharing economy). There is also the need for investigating new flexible and agile SC models that consider product modularisation strategies, postponement and "multi decoupling points" with a view to custom production and quick re-design of SCs.

6.3 Impact

The innovation path identified with the RITs can have significant impacts on SC performance. The future impacts expected from the development of the RITs for the CDSC strategy include:

- Increase of timeliness and accuracy of data on and from customer
- Increased customer satisfaction and loyalty
- Increase of active participation of customers in design and production processes
- Reduction of time to market
- Increase of responsiveness, shorter lead times
- Reduction of the number of returns.

7 Disaster Relief Supply Chain Strategy

Nowadays, modern SCs are more cross-border and integrated than ever before and they can be more vulnerable to disasters (Abe and Ye 2013). Disasters damage infrastructure and SCs, cause huge economic losses and negatively affect the global economy (Altay and Ramirez 2010). A IMF[1]'s report indicates that natural disasters such as droughts, floods, and storms can often cause damages totalling 50% of a country's GDP (mainly for not-developed countries), with indications that frequency and size of catastrophes have risen over the past 20 years. In Europe, in the period 1980–2013, recorded losses from climate extremes cost on average EUR 11.6 billion per year (European Environmental Agency 2017) and damages are projected to increase in the future with continued climate change (Schwartz et al. 2014).

In these catastrophic scenarios, the Disaster Relief Supply Chain (DRSC) is employed. Usually this kind of strategy is adequate to provide first and immediate emergency aid as well as longer term development aid for the re-construction (Oloruntoba and Gray 2006). The DRSC can have non-profit objectives and involves logistics that account for 80% of relief operations (Van Wassenhove 2006) and are primarily reactive, being performed through ad hoc design with extensive advance planning (Balcik et al. 2010; Dubey and Gunasekaran 2016). There are three phases within disaster management that DRSC follows, namely: preparedness, immediate response and reconstruction/rehabilitation (Van Wassenhove 2006). Information management, collaboration and agility can reduce complexities (Tomasini and Van Wassenhove 2009; Oloruntoba and Gray 2006) due to uncertainties and limited knowledge about the disaster. Therefore, it is important that quick information sharing through innovative technologies and increased visibility shall be proposed to facilitate the collaboration between the many different actors (Tomasini and Van Wassenhove 2009) facilitating also partnerships between private sector, public sector and relief organisations (Balcik et al. 2010).

[1] https://www.imf.org/external/pubs/ft/fandd/2019/12/pdf/fd1219.pdf.

Given the more and more unstable conditions, the DRSC is not only useful to face humanitarian emergency, but it can also be applied by industrial networks in order to reduce the disruptive impact of uncertainties and unpredictable events on production and distribution. For example, in the last months, the pandemic caused by Covid-19 have disrupted the world affecting more than 15 millions of people globally.[2] This emergency has forced the governments to close the boundaries and to put in lockdown the countries (such as in China, USA and most of EU countries) closing all the production and service activities. Therefore, the sanitary emergency has been followed by a deep economy crisis; OECD estimates that annual global GDP growth is projected to drop to 2.4% in 2020, decreasing around 0.5% while, due to the economic slowing down, the losses are calculated around 1 trillion $ (OECD 2020). For example in the USA more than 30 million of employees have lost their work in two months; in Europe, a report presented by ACEA (2020), has highlighted that about 1.1 million of workers have been affected by the closure of the automotive sector and the factory shutdowns have resulted in lost production amounting to 1.4 million motor vehicles in March. For companies it is important to invest into the long-term continuity of the SC, focusing also on mitigation strategies, prevention of emergency and on recovery (Fan and Stevenson 2018; Remko 2020) in order to reduce the risk of supply disruptions.

7.1 Specific Challenges for DRSC

A set of specific challenges related to the features of this strategy is here reported, representing the gaps to be covered with innovative approaches and tools as from the RITs in the following section.

1. *Need of high collaboration level in facing emergency*: the DRSC appears to be quite fragmented with a low level of collaboration between the actors involved; these actors coming from different sectors and with different background sometimes are not able to collaborate and communicate properly. In facing quickly such events and reacting to specific needs, there is a lack of standards between the involved actors and cultural differences.
2. *Develop "leaner" and more flexible SC*: the long lead times in combination with the lack of adequate and timely information sharing and shared tools to optimise local and global solutions can make it more difficult to respond quickly to the disruptive events keeping under control the inventory levels.
3. *Identifying talents in SC during the first aid*: the shortage of talent and skills gap have created the need for specialised and trained staff able to coordinate properly the resources during emergencies.

[2]https://covid19.who.int/?gclid=Cj0KCQjw6uT4BRD5ARIsADwJQ1-xZINZeB9iaMD4zUYl8rwgWFYqpWSgEurk8Nq8HRfR2AKDnELZ7rAaApFcEALw_wcB (accessed on 23 July 2020).

4. *Managing risk and disruption*: as SCs become increasingly complex, risk management is vital and the network need to be able to manage disruptions and overcome rigidity and lack of reactivity towards unexpected event.
5. *Facing inventory and shipping problems*: there is poor inventory management as disasters make it difficult to store relief materials at a single place. Also, the supply system deployed in disaster relief operations depends on transportation and communication related infrastructure that are frequently destroyed by the event. Therefore, there is need to use integrated 3PL capabilities in disaster relief SCs to support NGOs and governments in responding to disasters.

7.2 Research and Innovation Topics for DRSC

The most important research and innovation topics for the DRSC strategy are here described.

RIT.1: Multi-actor collaboration platforms for emergency

The development of multi-actor collaboration platforms can assure the management and coordination of goods and information flows to enhance collaboration between parties (Ernst et al. 2017) and inventory system. Multi-actor platforms, supported by resilient communication infrastructure, facilitate the information sharing in real time about the status of the emergency in terms of location of people in trouble, location of good and resources for first aid. Moreover, these platforms can manage donations, increase visibility and integrate all the actors involved (i.e. governments, aid agencies, private companies, donors, military, NGOs) who will get more accurate information. The use and integration of information derived from different systems can support the management of inventory and resources, transport and load consolidation. This helps to organise the delivery of goods for the first aid and the reconstruction phase, mapping countries and organisations with the right resources to ship straight away to the site of the disaster. The resources to be shared are both goods and technical staff able to support people during the emergency and organise in loco the first aid. Integration of autonomous systems is also necessary to assure delivery of goods in bad conditions. Moreover, it is essential that this kind of platform supports the collaboration with commercial SCs to organise the activities in a coordinated way. Finally, these multi-actor collaboration platforms can be used and enhanced in the preparedness phase (e.g. risk assessment, training and skills development) and not only in the response or recovery phases.

RIT.2: Crowd-help open platform for first aid

A crowd-help open platform for first aid shall enable citizens to share information in real time, support the creation of digital volunteer networks and the detection of actual needs of the affected population which, in turn, helps to mitigate the influx of unsolicited donations. This kind of platform promotes horizontal collaboration during an emergency. Citizens can be connected to the platform through their smart devices to share not only their position and instant needs, but also to receive indications on how to behave in bad situations or how to reach the nearest secure place, other information about changing environmental conditions or to share information about their health status and consequently receive indication about the behaviours to be followed. The use of mobile devices to communicate in a peer-to-peer way through collaborative platforms is essential to ensure the possibility to reach any people anywhere (Hafil et al. 2017). Moreover, this kind of platforms could facilitate the process of managing the donations, ideas and solutions as well as helping governments and NGOs to implement fast solutions not only in the immediate response but also during reconstruction. The crowd platform shall also help to train citizens and prepare them to deal with possible future emergency situations. The platform shall provide virtual courses to improve the skills of the volunteers and the professional staff who have to be prepared to support population wherever necessary. However, verification/moderation mechanisms or technologies (e.g. artificial intelligence and machine learning techniques) need to be implemented to avoid fake contents.

RIT.3: Models and tools to assure prompt response after emergency

Every disaster requires the configuration of agile/responsive SCs, planning standards in advance to overcome cultural differences. This can be enhanced by models and tools to ensure a prompt response after an emergency, such as the adoption of different technologies to accelerate the re-building phase, incorporating disaster risk reduction measures into the restoration of physical infrastructure and societal systems. It is thus important to implement:

- New technologies, including social media, big data and connected simulation tools, to develop applications for recovery that improve cooperation, communication, and collaboration. To facilitate the recovery planning process properly, appropriate and adequate resources shall be dedicated to data collection, analysis, and distribution. Such assessments are critical to enable governments affected by disasters to formulate their requests for assistance and plans post-disaster actions (UNISDR 2017).
- Technologies enabling quick response and fast re-organisation of manufacturing operations to produce the needed items for emergency in loco. The paradigm of containerised production and new 3D printing facilities could be developed (OCHA 2015).
- New optimisation systems to support inventory management, distribution networks for delivery of goods under difficult conditions.

Moreover, disaster relief standards and commitments need to be developed to assure effective assistance and common understanding. Finally, configuring the SC using local resources is also of high importance for a prompt response and reconstruction after emergency (Matopoulos et al. 2014); a beneficiary-focused, community-based approach need to be employed in the case of a post-crisis where beneficiaries become active members of the SC (Kovács et al. 2010)

RIT.4: Models and tools to handle valuable data for prevention and forecast

In adverse situations such as climate change and related disasters, humanitarian emergency, unexpected import duties, local disruptive events (i.e. plant firing with toxic emission) organisations need to be informed on time on several different dimensions that are not directly under their control, but can largely influence their operations. More specifically, models and tools that will retrieve and analyse big amount of data from different sources (both internally to the company and externally) need to be developed to handle valuable information for prevention and forecast. The application of this kind of information derived from forecasting should be linked to further innovation on the definition of tools for prompt re-configuration of SCs to make them adaptable to increased complexity and uncertainty. However, as it is extremely difficult for natural disasters to be prevented, these models and tools can help improving the humanitarian response and significantly decreasing causalities.

7.3 Impact

The innovation path identified with the RITs can have significant impacts on SC performance. The future impacts expected from the development of the RITs for the DRSC strategy include:

- Decrease of costs of recovery plans
- Increase of completeness of information needed for decision making process
- Increase of timeliness of data sharing
- Decrease of time for emergency response and for the implementation of recovery plans
- Increase of number of people engaged in dispensing aid.

8 Global Supply Chain Strategy

In 2018, the global logistics market was worth over 5.5 trillion euros,[3] while the global supply chain (GSC) management solutions market is expected to reach $29.1 Billion by 2027.[4] Moreover, the expansion of the GSC market is driven by the rapid increase of e-commerce industry, the change towards customised orders, the need for short delivery times, the strict standards compliance, the increasing use of location and communication. The globalisation is supported by the increase of goods and services exports seen between 2000 and 2019, 3.31% of GDP, and an increase of 3.38% on GDP on the imports of goods and services, both worldwide. The global sourcing strategy requires multiple suppliers worldwide, where companies consider procurement and purchasing across a global network, with lower costs and improved

[3] Statista, 2020. https://www.statista.com/statistics/1069868/total-global-logistics-market-size-region/#statisticContainer.

[4] https://www.businesswire.com/news/home/20201013005874/en/29.1-Billion-Supply-Chain-Management-Solutions-Market---Global-Trajectory-Analytics-to-2027---ResearchAndMarkets.com.

reliability, quality and access to technologies and new markets (Van Djik 2013). In the era of "time-based competition" the ability to respond rapidly to unexpected changes in demand, i.e. agility capability, is an important pre-requisit for GSC (Christopher et al. 2018). Companies should consider all sourcing options (home country as well as various near and far ones) and then decide the best for them. Reshoring trend (companies coming back to source or produce products in their home country) is also becoming a more viable option thank to enabling technologies that help companies to increase economies of scale and keep value in Europe. Looking at the downstream SC, with omni-channel sales strategy and multimodal distribution, GSCs are capable of providing decentralised distribution while holding multiple possibilities of customer-service channels in a multi-echelon system (Amirjabbari and Bhuiyan 2014; Onstein et al. 2018). Coordination and collaboration are other two important characteristics of the GSCs and trough the Physical Internet, they enable vertical and horizontal synergies for the use of resources in global networks, with significant gains in terms of efficiency and sustainability (ALICE 2014). In addition, the sustainability of the GSC is also considered with regards to distribution, where an attempt to promote "green" logistics through implementation of reverse logistics, emissions' assessments and sustainable logistics' procedures is consciously made (Grant et al. 2017).

8.1 Specific Challenges for GSC

A set of specific challenges related to the features of this strategy is here reported representing the gaps to be covered with innovative approaches and tools as from the RITs in the following section.

1. *Managing global financial flows and international agreements*: need for trusting environment among SC partners, through smart contracts that positively affect financial/bill settlement strategies. Furthermore, the globalisation of SC brings forth a multitude of currencies and heterogeneous regulations, policies and taxes, all of which contribute for a complex management of agreements among SCs players, while also producing alarming levels of uncertainty. Additionally, new business models are necessary to face new complexity level, where new funding schemes can support collaborations between traditional funding agencies (such as investment banks and private equity traders) and FinTechs.
2. *Increasing sourcing and distribution complexities*: not only financial flows are affected by the constant globalisation of SC processes, rather, the operational processes that determine the global strategies are even more impacted by this change. On that note, sourcing and distribution complexity management become increasingly concerning for global companies, with special focus towards difficulties in establishing standard quality checks and procedures on different locations, resulting in less consistency in product quality control.
3. *Increasing disruptive events at global level*: risk management in global SCs becomes a major issue regarding sourcing and distribution, since there is a

tendency for facing inventory and shipping related obstacles, such as the required variety of products offered on globally placed warehouses and the constant optimisation of distribution routes.

4. *Achieving seamless integration in long SC*: the combination of an increasing complexity, a lack of standardised practices of sourcing and distribution, and interoperability challenges with respect to communication on a machine-to-machine (M2M) level entails the focus point of achieving a seamless integration and synchronisation of production and logistics operations. On this aspect, the limited production capabilities, coupled with GSCs' characteristics that require different set-ups of production facilities, may be the starting point for driving SCs' configuration towards an overall integration of process, mostly achieved through extensive use of IoT and Communication Infrastructure.
5. *Promoting sustainable industry competition*: absence of widespread industry competition may lead to problems regarding concentration of power in multinational companies. Thus, there is growing need for establishment of well-designed regulatory frameworks and policies to be adopted by global actors, which may require strong diplomacy efforts of reference bodies (such as governmental branches for trade agreements or specialised agencies of each industry sector).

8.2 Research and Innovation Topics for GSC

The most important research and innovation topics for the GSC strategy are here described.

RIT.1: Global SC management with real-time optimisation and simulation

In the next years, GSC management will be affected by the full development and implementation of technologies currently applied in a jeopardised manner around the world with limited capability to integrate information and goods flows. Missing alignment in production and distribution technologies and IT infrastructure increase the difficulties with reaching SC standards. In particular, it is necessary to focus on the following research needs:

- New systems for tracking and tracing goods and services along the end-to-end SC, where the use of location technologies, smart sensors for production and packaging control comes into play. Implementation of smart contracts as a way to manage tiers of the GSC will increase responsiveness, agility and safety and security of the financial and information flows. GSC strategy needs to consider global financial flows, requiring the rapid advancement of distributed ledger technologies, all of which are still emerging and currently do not provide safe levels of cybersecurity for complex transactions.
- The use of Data Science with Big Data Analytics will also play an important role in the establishment of optimised end-to-end SCs, since the vast amount of data retrieved from sensors need to be filtered, analysed, selected and acted

upon. Communication Infrastructure, IoT technologies and cloud based computer systems must be developed and implemented in a timely fashion, in order to foster the improvements needed for the aforementioned technological requirements.

- Enabling the possibility to evaluate a quick change of suppliers in case of urgent necessity. Instead of rigid SC structures, flexible SC designs have to be developed as well as its quick evaluation.
- New advanced modelling and simulation can support companies thanks to real-time data in dealing with high levels of uncertainty, multi-format distribution channels, outsourcing. Smart dashboards linked to IoT devices implemented in the production lines, logistics centres and distributers among all actors of the SC can help to quickly react to any need worldwide achieving the coordinated planning and execution of SC operations.

RIT.2: Achieving integration through seamless interoperability

In a digitalised GSC environment, the increasing complexity of sourcing and distribution processes, combined with interoperability challenges regarding machine-to-machine communication and the need for widespread information flows along the network, demand extensive research in systems integration based on seamless interoperability. The customised IT solutions entailed by GSCs actors exponentially increase this issue, since a universal solution becomes increasingly more difficult to find with the growth of the number of actors. Therefore, a substantial effort to align along the entire value chain is expected to require:

- Efficient integration of upstream and downstream processes on all nodes of the SC, implying the development of novel solutions for deeper integration which are based on modular and scalable aspects.
- Development of "plug and produce" online platforms based on reference architecture models connecting the different actors of GSCs, increasing visibility for end-users and customers while also supporting the digitisation process. This will foster B2B transactions, information flows and provide suitable simulation environments for test-bed appliances and customisation capabilities.
- Development of holistic interoperability solutions regarding the different communication protocols, with special focus on M2M and M2S, which are used on the digitalised GSC regarding smart contract establishments and material- and financial- flows.

The reference architectures used for digital industrial manufacturing, combined with AI-driven machine learning and deep learning, as well as a concise framework of standardised norms and procedures, can be achieved through extensive use of IoT-enabled devices supported by responsive and agile Communication Infrastructure and Protocols, with the necessary computational brainpower for simulated environments (SC digital twins) in real-time, on-demand requirements. This would require great use of Data Science, as well as the implementation of distributed ledger solutions that may increase the level of security of the information exchanged among SCs' actors. The implementation of SC digital twins for the entire SC is paramount, and requires great knowledge and information management from the technical point-of-view, since it allows for real-time simulation capabilities and decision-making data storage. All of these are useful tools that may enable SC managers to look over the entire SC process, having the full transparency of information available for decision-making requirements, as well as being prompted with optimised strategic procedures from the virtualisation and simulation activities.

RIT.3: Global Shared Transportation Platforms

The geographical widespread placement of different suppliers and customers who purchase from overseas retailers through e-commerce channels, which are continuously developed offering more and more products and services, results in further complications and variables in sourcing and distribution. The advent of the Physical Internet, and its inherent consequences for global logistics providers, is a growing concern for future GSCs. Physical Internet Initiative can be considered an open global logistics system that combines physical, digital and operational interconnectivity by means of encapsulation, interfaces and universal protocols (ALICE 2014), which boasts huge advantages when relating to Global Shared Transportation Platforms (Montreuil 2011). In order to optimise the transportation channels necessary for sourcing and distribution on such large scale, the development of global shared transportation platforms with intermodal capabilities requires great efforts regarding quality procedures and assurance, as well as the effective implementation of standardised norms and processes to secure control over the increasing complexity of actors. Location Technologies and Communication Infrastructure, aided by IoT devices that connect all the transportation systems and nodes to collect data and AI methodologies are essential to facilitate the information flow of shipping procedures. These technologies will enable to realize autonomous vehicles, coupled with a fast, online, real-time AI-driven service that can gather, evaluate, decide upon information and relay actions for real-time optimisation of distribution routes, while considering intermodal possibilities that may increase the routes' agility, safety and reliability. Another research area is the design of flexible warehouses and fulfilment centres offering postponement services and acting as innovative showrooms. Special last-mile delivery services with customised scheduling and return-to-sender capabilities are also targeted to enable global logistics to "enter" the city. Such platforms should not only be able to display the correct position and information regarding companies' shippings, sales and purchases, but also to aid in mitigating risks related to conventional transportation methods. It is necessary to study transportation platforms connected to logistics digital twins for real-time simulation of routes, both within cities and between destinations, thus enabling companies to reach the most profitable, least risky solutions for their shipping requirements. Such a kind of digital transportation platform would enable effective track-and-trace, moving on from the current standard, which is focused on a single SC actor, to a broad overview, thus covering multiple actors on the same SC.

8.3 Impact

The innovation path identified with the RITs can have significant impacts on SC performance. The future impacts expected from the development of the RITs for the GSC strategy include:

- Increase of timeliness of data sharing
- Increase of accuracy of data
- Reduction of transportation costs
- Reduction of time in decision making process against uncertainty
- Increase of delivery services level
- Increase of transport sustainability performance
- Increase of multimodal shipping.

9 Human Centred Supply Chain Strategy

The aim of the Human Centred supply chain (HSC) strategy is the conception and development of SCs enabling the integrated and inclusive valorisation of humans, in order to contribute to employees satisfaction and well-being and to maintain humans playing a central role in production and distribution. Multiple factors are increasingly affecting quality of jobs and related skills. Highly-qualified jobs are projected to rise in the next future from 29% to 35%, while those requiring lower qualifications will fall from 21% to 15% (OECD 2014). Companies are facing disruptive changes driven by digital technologies, and certain skills are rapidly becoming obsolete while other new skills are required. For instance, software engineers, professionals in marketing, sales, manufacturing, law, accounting, and finance have to update their skills every 12–18 months (Deloitte 2017). For the next ten years, an increase in hiring SC talents with technical competencies and high level qualifications (Schröcker 2017) is expected, as well as leadership and professional competences and capabilities with cross-functional, digital skills and new talent acquisition/retention practices. Companies have to rethink the way they manage careers and deliver always-on learning and opportunities to improve workers' skills and develop training programs to create adequate profiles for future SCs to cope with: socio-cultural talent diversity (e.g. ageing workers, cultural diversity and gender issues) and competence management (e.g. labour shortages and skill gaps), at all levels, from white to blue collars. HSC needs to take into consideration not only training but also ergonomic, safety and security: according to statistics, in 2015 in EU-28 there were in fact more than 3.2 million non-fatal accidents and almost 4 thousand fatalities as a result of occupational accidents (Eurostat 2015). To effectively address all these different issues, future SCs must become increasingly inclusive, focusing on the involvement of people, who will be enabled to perform complex activities with much added value, in a safer and more secure workplace supported by innovative devices and tools brought by digitalisation (WMF 2019). The human centred technological change in the SC processes could result not only in cost efficiency and process flexibility but also in extended corporate employee responsibility by fostering socially and inclusive responsible practices (European Commission 2014). Therefore, humans are the central element at all levels and dimensions throughout the whole SC, also implementing diversity and equity policies.

9.1 Specific Challenges for HSC

A set of specific challenges related to the features of this strategy is here reported representing the gaps to be covered with innovative approaches and tools as from the RITs in the following section.

1. *Need of identification and development of SC skills*: while the digitalisation widens the specialised talent gaps in the EU workforce and creates talent shortage in the current marketplace, the context-aware identification of (hard and soft) SC skills is of vital importance to respond to the emerging needs of the market and better enable the sustainable management of networks. The identification of the new skills is needed to improve the effectiveness of the development of innovative learning experiences to updated the skills.
2. *Lack of training programs for workers in SC environments*: the human element in technology change management becomes important and specialised skill programmes should be designed taking into account human-centred organisational design principles to ensure the full implementation and usage of the new technologies which require advanced skills to managers, workers and drivers. The SC talent programmes, workforce development frameworks, and employee upskilling initiatives need to be re-designed to better unleash SC talent capabilities.
3. *Socio-cultural acceptance and awareness of future technologies*: the socio-cultural acceptance and awareness of future technologies can represent an obstacle for the successful implementation of technological change management initiatives. It is important to take into consideration the voice-of-employee when designing the future of work in SCs and to optimize technology-equipment user experience. In culturally diverse and global work settings, cross-cultural acceptance of technological enterprise solutions needs to be successfully managed. Employee upskilling interventions should take into account the socio-cultural differences in the workforce, as these differences directly affect the technology's perceived usefulness, perceived ease of use, user attitude and user behaviour.
4. *Lack of safety in the work environment*: the integration of emerging technology solutions, such as autonomous systems and robots, with the organisational settings requires technology contingency planning and workforce risk management protocols. Furthermore, considering the environmental risks of technology solutions (e.g. toxicity levels in nanomaterial solutions), technology evaluation

and monitoring processes should be re-designed in order to improve workplace health and safety conditions.

5. *Need for a social sustainable SC*: enterprises should incorporate a socially sustainable SC management approach while addressing the social issues of its SC base that are related to Occupational Health and Safety protocols and Corporate Social Responsibility protocols, among others. Furthermore, when managing the incremental digital transition in HRM and the digital transformation of SCs, making the technological systems, such as Physical Internet, socially responsible is of high importance.

9.2 Research and Innovation Topics for HSC

The most important research and innovation topics for the HSC strategy are here described.

RIT.1: New tools to enhance work environment

This topic shall aim at providing employees with a suitable working environment. Companies, and more than ever SC activities, base operational efficiency leveraging both on high level technologies and on workers' ability to cope with them with innovative interaction methods. In particular, collaborative robots sharing environment with humans supporting and relieving them have already been tested and are implemented in factories, warehouses and distribution centres. Further studies are necessary to improve functions and new human-machine interfaces based, for example, on visual and gestural movements for more accurate interaction with workers. Advancements are also expected in the use of exoskeletons to help workers (including the ageing workforce) in their activities, enhancing safety and productivity both in production and logistics. Research should focus on new actuators, batteries and advanced materials, as well as the development of functionalities to assure that the wearer and the exoskeleton are aligned. This research field includes the enhancement of the workplace through the design principles of ergonomics to ensure the comfort and wellbeing of employees, possibly integrating studies on: psychology to implement new analysis on human ability, capability and needs; bio-engineering to implement new tracking systems of workers' movements; mechanical engineering to develop appropriate tools for production and distribution tasks in order to improve people's interaction with products and systems. Finally, the use of Augmented Reality (AR) and Virtual Reality (VR) need to be developed with new low cost, ergonomic and comfortable devices, to make the interaction more natural for workers in a virtual environment, which simplify and improve tasks supplying information on processes. The devices will provide a continuous feedback of virtual objects through force feedback and will have to be auto-calibrated to easy adapt to the different operators.

RIT.2: Cyber and Physical Safety in new work environments

The flourishing of multiple human-machine interfaces and convergence of cyber and physical realms in SC management requires an integrated cyber-physical security operations management and risk mitigation approach in new workplaces to improve the safety and security of all workers involved in the networks. From the management standpoint, it is vital to protect the company's data access controls, critical infrastructure, and eliminate any possible security threats from increased human-machine collaboration, the use of autonomous technologies and the use of smart working (increased in the last period to ensure the safety of the workers during the health crisis due to COVID-19). From the workforce standpoint, workers needs to be updated via training and certification programmes, about the operating modes of safe human-machine collaboration and integrated cyber-physical safety requirements of the new workplace environments: the workforce has to be aware about cybersecurity, privacy, and data/information due to the rapidly increasing digital footprint of the value chains (WMF 2019). Moreover, to guarantee and improve safety in the working environment, new models should be studied to solve privacy problems when tracking and tracing operators' movements through wearable devices. New models to use data securely can help redefine the activities of the workers in case changes are needed in the SC. Considering the behavioural engineering aspects of human sensing applications, the autonomous and cognitive abilities of robots need to be improved. This means that workers and machines must be able to cooperate synergistically, sharing activities efficiently and safely. Cobots for both production and logistic processes, need to be equipped with the appropriate technology to have the sensory abilities to predict, prevent, and respond to the safety hazards in their environments. Research development of AI and the integration of new specific exteroceptive sensors (including ultrasonic, vibration and radar sensors) will improve the efficiency of prevention algorithms enabling robots to make real-time decisions autonomously and navigate within dynamic work environments. Moreover, research will have to ensure that the active exoskeletons (those that use energy sources) comply with increased human safety standards regarding the energy sources used as well as regarding the radiation emitted by electromagnetic waves from Wi-Fi, Bluetooth, etc. signals used by the various sensors. Finally, the health and the safety of the workers should be always the first priorities for companies, mainly during health crisis as in the last period, providing workers with all the safety devices, promoting the smart working and the social distancing reviewing the organisation of the tasks, form the assembly of products at the production lines to the handling of material in the warehouses or in the distribution centers and flows of people in the common spaces.

RIT.3: Technologies to identify, improve and assess workers skills

Technology will undoubtedly render certain roles in the workplace obsolete but at the same time generates a different set of roles. This is valid for digital innovation in SC management also. New methodologies to identify the skill gap and novel training programs supported by innovative learning environments should be studied, to simulate the workplace, to keep workers up to date and to help them remain competitive in the workplace also increasing investment in workforce education to reach the full potential of new technologies (WMF 2019). Digital platforms for competence management and training will support the provision of information for on-the-job training, delivering for example eLearning content to all the workers involved in SC processes or sharing the competence of human resources in order to face any possible issue adequately, both horizontally and vertically along the SC. The research challenge is to develop platforms where several different companies on the same SC can share training facilities beyond company boundaries. The development of new skills and their continuous updating, through the use of virtual training experience, need to be assessed at SC level to verify the skills attained, and manage the human resource more efficiently along the network. The paradigm of a teaching factory, already successfully implemented at manufacturing level (EFFRA 2016), can be further extended at SC level with initiatives, technologies and facilities that involve different companies in a SC to train people on production, distribution and logistics to develop the necessary skills at cross-company level. Moreover, it is necessary to study new ways of matching workers' digital skills to each specific field of activity and job tenure, taking into consideration the need to develop soft skills, such as flexibility, creativity and teamwork capacity. Humans must be both creative and prepared to innovate in manufacturing and logistics and they need to be able to work collaboratively, virtually and remotely, along the entire network with colleagues, customers and partners alike.

RIT.4: Management of ethical issues in new models of human-machine collaboration

It is clear that in a new working environment, machines (for example robots, autonomous systems) must collaborate with humans, rather than replace them. On the one hand, they are an operationally-efficient asset, as they can help workers to handle unpredictability in their workplace. On the other hand, they have a cognitive, complex, and context specific knowledge interpretation and assessment ability that can contradict humans. Research advancement in Deep Learning should be developed, based on human needs and with the aim of expanding and augmenting human capabilities. In this way, people will gradually trust machines/technologies, seeing them as added value rather than threats to their jobs. The ethical perspective of new technologies needs be approached in two ways: people who develop computer based algorithmic systems shall be aware of possible ethical challenges, including the unintended misuse of the technology; and, when moving towards advanced autonomous systems, systems themselves shall be able to make ethical decisions to reduce the risk of undesirable behaviour. While automated decision-making systems have the potential to increase efficiency and fairness at work, they also open up the possibility of new forms of discrimination that may be difficult to identify and address. The opaque nature of Machine Learning and Deep Learning algorithms challenges our ability to understand how and why a certain decision has been made by the machine, as well as to ensure fundamental values such as equity and justice. The prejudices of people who develop a technology easily infiltrate, explicitly or implicitly, the training data of algorithms, thereby causing discrimination and injustice. Inclusion of minority groups that now remain under-represented in the areas of computer technology can help to make diversity properly represented and, consequently support to overcome discriminations.

9.3 Impact

The innovation path identified with the RITs can have significant impacts on SC performance. The future impacts expected from the development of the RITs for the HSC strategy include:

- Decrease of risks due to incidents between workers and machines
- Increase of quality workplace
- Increase of number high skilled workers
- Increase of confidence with new technologies
- Increase of Job Quality Index
- Increase of capability to fill the skills gaps
- Increase of equity in technology usage.

10 Hyper-Connected Supply Chain Strategy

Nowadays, business and society are deeply influenced by an exponential increase in connectivity that lead to the definition of a hyper-connected world. For example, thanks to Internet of Things (IoT), connected devices at worldwide level will reach 75.44 billion by 2025, up from 30.73 billion in 2020 and the market for Artificial Intelligence (AI) is expected to grow to \$14.7 billion by 2025 (Accenture 2020). Digital interconnection is expanding across all industry sectors and the mastery of digital technologies in value chains offers relevant opportunities to create value for customers (Digitising European Industry—Digital Industrial Platforms 2017). Data originating within industrial contexts are considered “industrial commons” and its potential lies in so called ‘data-sharing collaboration’ between SC partners. The hyper-connected world of the future will comprise of environments transparently enriched with sensors, actuators, devices, machines, and computational elements that are interconnected and collaborating (Afsarmanesh et al. 2016) and several initiatives at EU level have been undertaken to connect factories. The full implementation of technologies such as digital platforms or decentralised exchange of information empowers all the entities of a network to share information and the virtual elements communicate both horizontally and vertically. This transformation of the SC will enable the development of services to become more valuable, accessible and affordable. It is expected that Hyper-Connected Supply Chain (HCSC) will integrate not only continuous physical flows, but also respective information and finance flows (Büyüközkan et al. 2018); it thus allows the synchronisation of interactions between the organisations supported by intertwined digital technologies for nodes and edges integration. Once implemented, the HCSC will enable end to- end visibility and collaborative relationships through adequate data disposal. The aim of the HCSC strategy is to create a collaborative and integrated eco-system where actors from all the different levels of the SC are involved in the process of transforming data into value to improve the performance of the entire network.

10.1 Specific Challenges for HCSC

A set of specific challenges related to the features of this strategy is here reported representing the gaps to be covered with innovative approaches and tools as from the RITs in the following section.

1. *Technology integration for seamless connection*: lack of standardised data and of a common integrated and secure IT infrastructure due to heterogeneous applications in each SC node causes mismatching of data between the nodes of the network; moreover, the lack of technology alignment at different levels of the SC generates interoperability problems and consequently it entails a low level of the quality of shared data. The technology integration problem is also strictly linked to issues of cybersecurity.
2. *Dealing with complex data environments*: each node of the chain can produce an enormous amount of data spread in many different repositories and information from the external environment has to be elaborated to face uncertainties and disturbances. It is difficult to integrate them in a SC framework enabling the seamless sharing of information to improve the performance of the entire network.
3. *Real time visibility and traceability* of the material, information and financial flows, that need to be traced in real time along the chain to avoid an untrusted and low collaborative environment. A unique source of information must also allow a complete verification of product data and finance information authenticity and quality.
4. *Role of humans in hyper-connected environments*: Nowadays, there is a shortage of high-skilled operators with the right skills to use new digital technologies; moreover there is a lack of trust in automation, data management and autonomous systems to be overcome.

10.2 Research and Innovation Path for HCSC

The most important research and innovation topics for the HCSC strategy are here described.

RIT.1: Towards the implementation of a Data-Driven model

The valorisation of data along the SC is quickly evolving into an essential step for companies to build collaborative models. The objective is to encourage coordination and maintenance of information symmetry across different SC entities, with the final goal of creating agile and responsive SCs. They will become more and more dynamic: each actor generates an exponential amount of data from cyber-physical systems, industrial IoT, monitoring sensors from any tier of the chain (shop floor, distribution centre, consumer and transportation system). The full implementation of a data-driven model requires the development of new solutions to increase the quality of data, which needs to be accurate and consistent, and ensure timeliness and completeness (Hazen et al. 2014) to enable the harmonisation and the enhancement of data coming from heterogeneous sources (Viriyasitavat et al., 2019). New AI solutions, machine learning and deep learning solutions can help to extract meaningful information from multi-variant and multi-scale data, for unambiguous decisions in every day production, and delivery decision assuring quality and trust (BDVA 2018). This can also help to find unexpected patterns for the optimisation of the SC processes.

RIT.2: Platform based SC to support the creation of collaborative ecosystems

Digital platforms make data related to factories, logistics centres, and transportation providers easily accessible and shareable anytime and anywhere (ManuFUTURE 2019). Platforms allow the full integration and alignment of the actors in collaborative eco-systems and enable the creation of a SC digital twin, demonstrating the real-time status of the network to obtain an overview of the entire chain and drill down along it. Further developments are required for:

- Upstream SC platforms to integrate suppliers and outsourcers, until the alignment, and monitor the network distribution.
- Downstream SC platforms to integrate warehouses, distribution centres, and sales channels to create a stronger relationship with market and reinforce customer loyalty and involving customers during design, production, and delivery of the product.
- Horizontal platforms for human resources management to exchange information with employees on tasks, training sessions as well as monitoring safety and skills, while respecting their privacy.

The ecosystems enabled by platforms are based on the integration of different technologies and it is necessary to assure seamless and secure data-sharing for all platform users (Büyüközkan and Göçer 2018; Farahani et al. 2017) and consequently guarantee the interoperability between cloud systems and other information systems. Both open and closed platforms should be studied taking into consideration specific needs. The adoption of reference architecture, semantic technology and standardised frameworks will increase not only the interoperability but also the collaboration and trust throughout the chain.

RIT.3: Future transportation for connected SC

In recent years, progress in the development of autonomous technologies and its application in different fields like transportation and mobility has exponentially grown. However, there are still challenges to be faced like level of autonomy, complexity, safety, availability, controllability and comfort (ECS 2019). It is important to further research on how autonomous systems react in challenging and unpredictable situations (as for example unavoidable crash), analysing autonomous behaviour in increasingly complex environments (ECS 2017). The development of autonomous systems depends not only on the improvement of their functions, but also on their capability of connecting with other types of autonomous transport systems; to develop large-scale and cross-border connected systems of autonomous transport, for example drones, autonomous trucks, trains and cars. The autonomous systems involved in outbound and inbound logistic activities require an innovative and resilient communication infrastructure, an integrated network of sensors and a deep digital transformation for urban areas to guarantee optimised management of the transportation as far as the end of the chain, with the consumer in modern cities. Moreover, user awareness and acceptance of the autonomous transport system has to be increased (ERTRAC 2018).

RIT.4: Methods and approaches for the traceability and transparency of SC processes

The need of integrated track and trace solutions to ensure monitoring of products and processing of information on different levels of the network is twofold: on the one hand, it is important to ensure efficient data collection; on the other, it is necessary to implement solutions to verify the product and information along the chain. Infrastructures to collect information from different tiers of the network right through to the final consumer are necessary: new IIoT, advanced sensors and location technology will ensure monitoring products and processes, collecting data in real time. Moreover, the development of new smart products ensures continuous integration to consumers to offer new services and collect data to measure the performance until (and after) the end of its life. Decentralised systems such as a distributed ledger solution (i.e. blockchain) increases SC transparency, reinforcing credibility of the information, with real-time tracking enhancing the safety of the products along the network (Wang et al. 2019; Viriyasitavat et al. 2019) and the transparency of the financial flow. Blockchain technology ensures stored records are accurate and from a verifiable and single source (DHL 2018). It is necessary for the next years to invest in technical limitations to be overcome, such as scalability problems, computing power requirements and high energy consumption. As the perception of data value gaining importance in the global value creation, there are approaches where to invest like the one proposed in IDS[5] which enable global dynamic data and business transactions between participants across all domains, sectors and industries without establishing a central infrastructure, thus peer-to-peer, linking single objects to entire platforms.

RIT.5: Cybersecurity to enable protection of data in SC

HCSC requires high level of trust between all the actors involved and poses significant challenges in terms of data security since the deep connection along the entire network forces each actor to exchange digital information with the outside world: a seamless flow of data and cybersecurity represent relevant challenges. The development of tools and services guaranteeing an adequate level of data security for digital collaboration in value chains is a priority. These tools need to ensure secure communication in digital transactions and data integrity during data exchange within and across the chain, and developing a stronger communication infrastructure. A system-centric view on security and privacy needs to be complemented with a data-centric view because the protection of data cannot stop at each system's border but have to be applied over the full lifecycle of the data and therefore along the entire network (European CyberSecurity Organization 2018). The management of cybersecurity has also to provide transparency on where data resides, who has access, and for what purpose.

[5] https://www.internationaldataspaces.org/our-approach/.

Continuous Monitoring and Certification systems of Data Integrity and security are requested (European CyberSecurity Organization 2018). Security Service Level Agreements need to be designed at each level of the SC identifying the model and policies on how data can be used between actors without compromising business privacy. This serves another valuable purpose, i.e. maintaining good relationships with customers, who themselves are evolving naturally into more and more data sources, taking into consideration the new regulations promoted by EU Commission regarding data privacy (i.e. the new General Data Protection Regulation-GDPR).

RIT.6: New approaches to face increasing uncertainty and complexity

The coordination and configuration of the SC has to take into consideration the numerous external variables and drivers that have a strong impact on the strategic and operational decisions that companies cannot govern. These variables increase the complexity of the network and make it more difficult to optimise decisions. New models to analyse the influence of exogenous changes to SC processes more effectively are needed. The SC is similar to a complex adaptive system, because it is non-linear and dynamic, where the interconnected entities have to proactively respond to changes from both the external environment and the system itself. Although each actor operates at a different level and follows different objectives, the resilience of SC is a collective outcome (Tukamuhabwa et al. 2015); moreover, when a disruption occurs, systems has to learn to be anti-fragile: it would not lose but profit from the effects of disruption (Zitzmann 2014). Therefore, for a HCSC, it is necessary to create new tools and models to hook up the changes and consequently adapt the product, processes, production and delivery systems in a coordinated and systematic way. Principals of cognitive adaptability, self-diagnosis and self-resilience need to be put in place through the development of new tools and models supporting forecasting, production planning as well as inventory and transportation management.

10.3 Impact

The innovation path identified with the RITs can have significant impacts on SC performance. The future impacts expected from the development of the RITs for the HCSC strategy include:

- Increase of timeliness of data elaboration
- Increase amount of data sharing for the decision making process
- Reduction of processing time
- Increase of alignment between production and logistics data
- Improvement of data accuracy
- Increase of capabilities to face cyber-attacks.

11 Resource Efficient Supply Chain Strategy

Resource scarcity has become an important concern for companies, policy makers and researches as most of the traditional business models and production systems have proved to be unsustainable when it comes to the use of resources (Balatsky et al. 2015). Water scarcity has been identified as a higher risk than oil: demand for freshwater is projected to be 40% above current water supplies by 2030 (Sachidananda et al. 2016). If energy intensity remained the same over time, global energy demand would grow in lock step with GDP, almost doubling between 2017 and 2040. However, global energy demand is projected to grow only by about 20% from 2017 to 2040 because continued efficiency improvement lowers the energy intensity of the global economy (Exxonmobil 2019). In particular, industrial energy demand will raise by 50% (Exxonmobil 2016). Moreover, the volume of solid waste is expected to increase to 2.2 billion tons by 2025 (The World Bank 2012). Although the complexity of manufacturing and distributing products and services varies among different process and materials, waste is a common issue for all sectors and markets (Singh et al. 2017). Given the business and environmental costs of procurement, having a Resource Efficient Supply Chain (RESC) strategy is of crucial relevance for the successful structuration of eco-efficient cost-saving programs and green SC initiatives. While addressing all the dimensions of triple-bottom line and mutually reinforcing elements of sustainability, RESC strategy envisages the cost- and eco-efficient integration of both open- and closed-loop life-cycle systems (i.e. product design, material sourcing/selection, manufacturing processes, delivery of the final product, product return and end-of-life management of the product). The implementation of RESC strategy aims to increase the strategic compatibility, collaboration and inter-organisational awareness among SC partners. This strategy comprises four mutually inclusive, pro-environmental, and behavioural elements (Matopoulos et al. 2015): resource-aware; resource-sparing; resource-sensitive and, resource-responsive. The implementation of RESC towards circular economy can be supported by zero-waste incentives, fostering the integration of environmental management principles with industrial networks and lean and green SC strategies. In combination with the reverse logistics approach, zero-waste vision can be implemented with the harmonious blend of green procurement practices and total quality management (European Parliament STOA 2017).

11.1 Specific Challenges for RESC

A set of specific challenges related to the features of this strategy is here reported representing the gaps to be covered with innovative approaches and tools as from the RITs in the following section.

1. *Resource efficient innovation modelling for end-to-end solutions*: need to create binding targets, raise awareness for eco-innovation, and develop frameworks to

design, develop, and deploy integrated information control architecture mechanisms for a successful planning and sustainable implementation of end-to-end resource management principles using transparency via digitisation.

2. *Energy and emissions management in the manufacturing and distribution of products and technologies*: energy consumption and emissions need to be managed and reduced to the lower possible level, both in case of new and current products. A broad commitment is needed to face this challenge, including the participation of policy makers, managers, and researchers.
3. *Limitations of regulatory frameworks for successful implementation of RESC*: eco-innovation enabling regulatory cooperation mechanisms and standardised waste management protocols are needed while fostering proactive policy-to-business dialogue platforms. More specifically, environmental regulators need to engage more with other regulators in order to better assess, develop, and disseminate resource efficiency principles.
4. *Improving energy systems and diversifying eco-efficient energy power sources for full exploitation of digital technologies*: one of the fundamental challenges that mankind has to face in the next few years is energy supply, its storage and conversion with the lower impact possible on environment. The way humanity has developed during the last two centuries lead to unsustainable production and consumption models and, although some improvements have been achieved, much more has to be done.
5. *Limited feedstock of raw material*: the supply of some rare and scarce raw material can become difficult even more if these are the core elements of new and smart products (e.g. lithium-ion batteries for electric vehicles).

11.2 Research and Innovation Topics for RESC

The most important research and innovation topics for the RESC strategy are here described.

<u>RIT.1: Zero-waste production and logistics</u>

To be efficient, the elimination of waste has to be considered at all stages of the network, requiring a broad commitment and partnership. Achieving a SC with zero waste footprint involves thus further research on several areas such as a redesign of the resource lifecycle through new tracking end-to-end systems and continuous performance assessments from procurement to packaging design and to all the production and distribution processes. It is important to reduce frictions in the intermediation of resources along the network and develop SC that are strongly programmed to reduce or eliminate waste and, at the same time, ensure minimal use of scarce environmental resources in favour of renewable energies and closed materials cycles. Moreover, a further development of methodologies, technologies and tools along the SC is expected that can support shared and integrated management of maintenance, quality control and logistics, to support zero-waste. For example, the use of IoT and the advanced analysis of the data, can model and forecast the state of degradation of the machine and the other assets at production and distribution level. These models will be able to predict deviations and the impact of a defect/waste on the subsequent SC stages and to identify proactive solutions to eliminate waste.

RIT.2: Traceability and management of product and processes information for resource efficiency

The introduction of monitoring and measurement solutions is essential in any industrial area to implement an efficient use of resources. Companies need to design, develop, and deploy an integrated control architecture for information coming from products and processes along the whole network. Related mechanisms are expected to optimise resource-efficiency of manufacturing and distribution processes by improving end-to-end traceability, creating cross-sector resource integration channels and therefore increasing SC robustness as well as the management of scarce resources. Being able to track and trace products, materials and process information in real time allows an increase in responsiveness and agility of the whole SC processes to be efficient. Further research is necessary to fully implement the adoption of smart sensors, location technologies and vision systems in production and distribution with applications like: replacing manual sampling procedures with automated and online sampling and analysis; providing important process data in real-time (temperature, flow and pressure, travel conditions); collecting data on both product and process for failure analysis, as well as on workers, drivers and operators enables defect, delay detention and product movement identification. Research efforts are required also to design and develop advanced, durable and low cost sensors that can be used where the process environment is hostile (e.g. high temperatures) or requires high resolutions of time and/or space that cannot be met by current technologies.

RIT.3: New models and technologies for resource-efficient transportation

Transportation represents a key decisional area in a RESC, especially for SC characterised by global transport, with extensive use of cross-docking areas and distribution hubs. In order to reduce transport costs, empty loads, environmental impact and new models of partnerships should be investigated. Shared transportation platforms can leverage new kinds of transportation management, thanks to better information sharing between transportation owners, logistic providers, warehouses etc. In this context, research needs to focus on the definition of models to facilitate the use of multimodal transports enabled by the combination of different transport means (i.e. trucks and train, train and vessels, trucks and drones) for which it is necessary to configure new hub networks. New methods and tools supporting the optimisation of dynamic decoupling points, cyber-sorting, lean loading and unloading operations are also necessary to increase resource-efficiency based on minimisation of journeys, use of cleaner transportation and introduction of new fuels. The alternative transport technology landscape of the EU, particularly the commercial procurement of electric vehicles (EV) powered by renewable electricity, are improving the vehicle efficiency in transport logistics towards carbon-neutral SCs. Nevertheless, there are still many open issues concerning for example: EV manufacturing technology levels; development stages of refuelling infrastructures (e.g. smart charging points); the varying country-level regulatory conditions for battery recycling (e.g. life-cycle costing) and EV charging prices. New research is necessary in order to develop transportation means that adopt Alternative Propulsion Systems, decarbonised and energy-standardised, and to study how these can be properly integrated among them and with the SC logistics and manufacturing processes. The impact of new transportation routes (like new Silk Road, or improvements to existing EU corridors) should be further studied, not only in terms of infrastructure and environment, but also with respect to the re-organisation of SC flows, location of factories, warehouses and distribution centres with models that take into consideration both private and public interests.

RIT.4: Monitoring and management of energy consumption

Energy management includes the planning and operations management of energy production and consumption activities. The following topics should be addressed:

- Identification of the origins of energy consumption in factory systems and GHG emission footprint at all stages of SC by combining manufacturing operations management with product lifecycle management, using low-cost microprocessors in electrical equipment of the factory systems, integrated in an Energy Management Systems (EMSs). This should be supported by energy cost reporting software and protocols enabling the end-to-end tracking and control of industrial energy consumption.
- Measuring the energy consumption and GHG emissions within the whole SC, and taking into account also the indirect and secondary types of consumptions and emissions (e.g. energy necessary to load trucks, and not only the necessary fuel).
- Developing novel schemas for enhancing peer-to-peer load, storage, and energy sharing mechanisms, managed on local network infrastructures of distributed energy systems and industrial IoT base of the factory systems. Development of peer-to-peer energy market platforms, where companies with demand peak can ask support to other companies in complementary ways.

Energy monitoring systems can use the IoT architecture and incorporate various technologies. In addition to real-time energy consumption information, energy monitoring systems can identify points of energy waste, or the excessive consumption of damaged devices. Data science and AI are also important technologies for the development of this strategy. Another interesting field of research concerns the worldwide distribution of scarce energy resources through intelligent SCs.

RIT.5: New approaches to energy storage

Complementary to energy consumption management, energy storage is an important component of energy efficiency and has a significant impact on SCs. The energy storage industry is constantly evolving and providing a wide range of technological approaches to manage energy supply in order to create a more resilient energy infrastructure, assure cost savings and increase sustainability both in industry and society. With the adoption of renewable energy resources, energy storage becomes even more important as these sources are often intermittent, for example producing energy only when the sun shines or the wind blows. In addition, storage technologies also improve energy quality through frequency regulation, allowing companies to produce energy when it is cheaper and more efficient and provide an uninterrupted source of energy for critical infrastructure and services. Moreover, large-scale energy storage enables the company's electrical system to operate more efficiently, which means lower costs, emissions and more reliable energy. Given the ongoing developments of different approaches (i.e. Solid-State Batteries, Flow batteries, etc.), there is the need for further research to properly balance the investments in energy storage systems according to the SC processes and the peculiarities of each single SC. In particular, for the successful implementation of these systems, it is necessary to investigate on well-functioning, locally significant, and context aware interaction protocols, distributed coordination of SC agents, optimal energy control, and value recovery.

RIT.6: Improving data mining processes

While industry 4.0 applications are paving the way for implementing agility in manufacturing and logistics practices, industrial energy efficiency becomes a core area of concern, as the energy information becomes more scattered and distributed, owing to the co-deployment of multiple, energy consuming manufacturing tools (e.g. mobile and wearable devices, alternative propulsion systems, technologies for visual computing). In this context, intelligent storage and analysis of energy-data is needed to improve energy management decision-mechanisms at operational and strategic levels, reducing carbon intensity and electricity consumption. Moreover, even if new technologies are important allies in order to achieve resource efficiency, they can bring with them new and challenging issues. It is broadly recognised today that energy consumption in data centres are becoming a global problem. Blockchain, for example (particularly cryptographic currency mining) requires large amounts of energy consumption, creating a serious environmental problem if not properly managed. In this sense, further research is needed to allow the environmental sustainability of the inevitable grow of technological innovations.

11.3 Impact

The innovation path identified with the RITs can have significant impacts on SC performance. The future impacts expected from the development of the RITs for the RESC strategy include:

- Decrease of waste generated in SC
- Reduction of delivery time
- Decrease of utilisation of fossil resources and CO_2 emissions
- Reduction of energy consumption
- Increase of renewable energy utilisation
- Increase of energy storage capacity and reliability.

12 Service Driven Supply Chain Strategy

Nowadays, services count for almost 75% of European GDP (Eurostat 2018), and the boundaries between physical goods and the services that companies offer are becoming increasingly blurred. Indeed, many product manufacturers are integrating services in their value proposition to raise the level of differentiation and guarantee a higher profitability and stability of revenue. The so-called "servitization" is one of the major trends characterizing recent transformations of companies' business models across a wide range of industrial sectors. The rationales behind this global phenomenon include the opportunity of generating competitive advantage and containing costs (starting from R&D), locking in customers and increasing their satisfaction, locking out competitors with a differentiated value proposition, and also enabling environmental sustainability, by managing the complete lifecycle of assets (Giardelli et al. 2014). Servitization entails the evolution of a product-centric to a service-centric business logic that has several implications: the complexities of interactions with multiple stakeholders, the necessary change of mind-set in the collaboration with SC partners and the risk-sharing needs due to the uncertainties of the shift to the service-centric business model (Giardelli et al. 2014; Zhang and Banerji 2017). Indeed, the shift towards a Service Driven Supply Chain (SDSC) strategy requires a change from transactions to relationships, from suppliers to network partners, from elements to ecosystems (Neely et al. 2011). The SDSC aims at the establishment of an increased service business orientation and the addition of services or a focused combination of goods, services, support, self-service and knowledge building up to a service-centric SC structure. The capability of offering services as complements - or even substitutes - for available products, enabling new business models and relationships in the supply base, requires the added capability of dealing with local specific needs and partnerships with service providers. Moreover, companies traditionally linked to products manufacturing are progressively embedding digital services into physical products. Digital technologies are transforming the SC structure and the power dynamics in both downstream and upstream networks, due to reductions in production and transport costs, and the identification of different ways of engaging with customers (Vendrell-Herrero et al. 2016).

12.1 Specific Challenges for SDSC

A set of specific challenges related to the features of this strategy is here reported representing the gaps to be covered with innovative approaches and tools as from the RITs in the following section.

1. *Developing collaborative models to support the shift to SDSC*: encouraging and accelerating trustworthy collaboration and sharing of knowledge to support the shift to service-centric business, to provide reliable services, to enhance value capture according to the new power dynamics in the SC, to successfully share

resources. There is the need to conceptualize, configure or manage relationships successfully and integrate the members of the new service ecosystems (Vural 2017), especially for value co-creation.

2. *Need of workforce with expertise in services and digital technologies*: services require specialists with new types of knowledge, especially in technologies such as IoT and big data analytics, that are spreading in different industry sectors (Business Innovation Observatory 2016).
3. *Managing IP protection issues, information sharing and cybersecurity in product-service systems*: product firms integrating (digital) services in their offer should leverage on their unique resources, e.g. intellectual property rights or tacit knowledge, and deal with protection issues when these are outsourced, e.g. in B2B platforms, and a value co-creation perspective is considered.
4. *Dealing with drivers and implications of servitization with regard to digitalisation and sustainability*: digital technologies can be both a driver and enabler of servitization, e.g. in business model innovation towards digital servitization that mainly empower downstream companies. Moreover, services can be used as a way to reduce resources consumption and waste within the paradigm of circular economy models.

12.2 Research and Innovation Topics for SDSC

The most important research and innovation topics for the SDSC strategy are here described.

RIT.1: Managing digital servitization of the SC

Driven by new business models and consumer habits, the so-called digital servitization encompasses technological, organisational and strategic challenges. Research advancements on AI and enhanced connectivity solutions can support the efficient analysis of data from customers and users to develop new and better product-service systems (ManuFUTURE 2019) and capitalise on them in future digitally-driven markets. There is the need to understand how the data economy paradigm affects the digitalisation of the overall SC, including the creation of collaborative models based on platforms, and their potential benefit for SCs and society as a whole. Indeed, platform-based business models such as the ones of Uber and Airbnb enable interconnections between a multiplicity of suppliers and customers. These interconnections lead to an ecosystem perspective that moves from the ownership of resources to the capability of creating better matchings between supply and demand markets, reshaping the decision-making and operations processes throughout the company and its SC boundaries. Innovative service business models enhanced by digitalisation include also services for production scheduling and machine and process optimisation, data-driven services, and Manufacturing as a Service, where manufacturing becomes fully service-oriented with small scale productions at a lower cost. While gaining efficiency in resource utilisation along single and multiple SCs, these demand-based models challenge the current manufacturing paradigm. It is necessary to study the implications for the relationship between companies in production networks, with the emergence of new SC models, and on the competitiveness of the overall SC. Moreover, further investigation is required on the interaction between IT systems, digital technologies as IoT and factory processes to sustain the ecosystem perspective.

RIT.2: Dealing with changes in business concepts and SC processes in servitized SC

The innovation in services provided to final customers, and the integration of services into product offering, result in changes to business operations (from back-office to supplies), SC structures and ways to integrate knowledge from a variety of network actors to maximise added value. Servitization of manufacturing and innovation in services can change the leading position of the focal company, foster the entrance into the market of new players with improved ability in service provision, and redefine the tiers in the overall SC. These changes can have severe impacts on:

- Power dynamics and incentives for each agent and SC tier
- Intellectual property and ownership of newly delivered solutions
- New processes and interactions between physical, information and financial flows.

Firstly, a SDSC aimed at collaboration should identify orchestration mechanisms and targeted goals for each agent in order to reach the global optimum performance for the overall SC. Secondly, studies should examine not only how servitization enables new value (co-)creation, but also how this value shifts or is shared along the SC, in terms of intellectual property and ownership. A reference model needs to be promoted for assessing organisational efforts, with defined roles and responsibilities, and related technologies, including distributed ledger, identification technologies and cloud computing for ensuring traceability and transparency on single efforts of all SC actors. Finally, further research should address the evaluation of the financial flows and payment systems of new business propositions, with specific service design methods that enhance the sharing of revenues (and long-term risks) among involved stakeholders in a continuous interaction. Indeed, a key challenge for solution providers is to reach the forecasted performance over time and in the overall SC, and configuring the bundle of services accordingly. New scopes of application of IoT and connectivity solutions, reconsidering related costs and benefits, should also be promoted to better tailor services that are acquiring a major part in the value offer, such as after-sales support and maintenance.

RIT.3: Open innovation and value co-creation for integrated product-service offer

In order to co-innovate product-service offerings in the most efficient and effective manner, SDSC should progressively evolve into new forms of collaboration. These advancements facilitate the necessary knowledge exchange and collaborative learning processes among all SC actors, starting from the involvement of customers in the value co-creation process as direct users. An investigation on the characteristics of a SC that is designed to make the most of innovation opportunities, for new product-service offers, entails several steps. These include: identifying the rationale and the available resources for co-innovation; taking advantage of available technologies (e.g. platforms) for sharing ideas and facilitating knowledge transfer; coordinating and aligning the efforts in innovation made by the different SC actors (and also other external sources); defining common policies and patterns of IPR for dealing with possible conflicts and increasing operational performance while maximizing value created. Single SC actors could act as innovation hubs, or new physical places (or virtual platforms) could be created along the SC network, where start-uppers, researchers, and companies can interact and test new ideas for product-service offerings, with the support of digital technologies and related equipment.

RIT.4: Innovative logistics paradigms and intelligent transport systems for service-driven SC

The European Commission is showing growing interest towards logistics and mobility solutions aimed at dealing with the requirements of the "on demand economy", driven by the growth of awareness towards autonomy (and increasing importance of intelligent transport systems) and sustainability. This is in line with the key relevance of circular economy and urban manufacturing approaches, which require technological advancements beyond collaborative efforts in value chains and logistics. Specifically, the new paradigm of the "Mobility as a Service", mainly enhanced by digitalisation, entail key opportunities to be applied to freight transportation and delivery services. Firstly, research could investigate the implications of adopting this paradigm on the structure of logistics network, the existing contracts and the business models of third party logistic providers. These could include a much more flexible system (e.g. payment of a monthly fee) for people and companies, and the value creation from different actors to benefit from transport and intralogistics services. Secondly, focusing on technological advancements, new research towards the creation of new services supporting more efficient, cost-effective logistics should consider the level of full driving automation. Future studies should focus onnovel approaches for both minimizing routes and number of freight transportation vehicles (especially in cities), and maximizing the integration between logistics, manufacturing and process industry through an enhance intelligence of delivery systems. Examples of innovative developments include the creation of large-scale, cross-border connected systems for seamless, optimised and multi-modal services for intra- and inter-logistics, and the connection between smart products and intelligent trucks directly communicating with warehouses management systems, enhanced by IoT.

RIT.5: New models and tools for secured and transparent data sharing and big data analytics in the service-centric SC

Managers and SC operators require to increase knowledge and awareness of markets, production or collaboration with partners, to face changing demand requirements in terms of services and related price. Customers themselves are becoming data suppliers and are also willing to receive data as a service, taking into account the issues of privacy and security of shared data. An extensive amount of data is also increasingly collected by sensors, IoT and identification technologies adopted to monitor both product and service processes. On the one hand, advanced tools and methods of Big Data and Analytics are considerably raising their profile and shaping the relationship with customers. Also the use of mobile and wearable devices enhances new capabilities for decision-making and delivery of services with an increasing value both for customers and providers (including upstream SC tiers). On the other hand, the ever-changing demand and shift to a SDSC are challenging single actors with vast amounts of data, and practices (and tools) for advanced data management are essential. This also entails open organisational and structural issues on data sharing, within both single organisations (e.g. between SC and marketing departments) and the overall SC (e.g. with more visibility on manufacturers and first and second-tier suppliers). New practices should be aimed at a global eco-system of data-driven services, where an end-to-end view on the supporting operations between the different actors should be ensured by e.g. adopting a distributed ledger, as well as dedicated tools for validation and security of data preserved. Collaboration setting and data/information exchange specifications have to be fixed accordingly for ensuring integrity and trustworthiness of data, systems and processes. On a prioritised basis this requires new models for cybersecurity management.

12.3 Impact

The innovation path identified with the RITs can have significant impacts on SC performance. The future impacts expected from the development of the RITs for the SDSC strategy include:

- Reduction of waste (physical goods)
- Reduction of resources utilisation thanks to integration of manufacturing and logistics
- Reduction of stocks (assets)
- Increase of SC responsiveness to final demand
- Increase of transparency along SC
- Improvement in value offer
- Introduction of new sharing models
- Increase of number of agreements for collaborative innovation
- Reduction in lead time.

13 Urban Supply Chain Strategy

The Urban Supply Chain (USC) is intrinsically related to the specific context of urban areas. Due to the rise of the urban population and the extension and multiplication of urban areas worldwide (over 68% of people will live in urban cities by 2050—United Nations 2019), the urban context becomes more predominant. Critical issues arise in the context of increased cost of living, pollution and poor air quality, traffic jam, poor food quality. In the context of SC, manufacturers and their suppliers will have to be integrated closer to their customers connected via a flexible interface. This integration is driven by the spread of new production technologies, such as additive manufacturing, and the rise of smart cities, characterised by high connectivity and new sustainable urban mobility (Manville et al. 2014; Dirks et al. 2010). Local goods, local food supplies and short circuits for delivery are in high demand (Grando et al. 2017). Due to a high level of customisation and the request of sustainability of products, the focus will be on small scale manufacturing systems in urban areas, with the growing importance of fab-labs and local producers. This kind of SC also tends to reinforce the entrepreneurship within the local community. The expansion of the urban environment involves a more complex development of the city logistics, impacting on the different flows (assets, people, vehicles etc.). With the multiplication and the intensification of these flows, it is of primary importance to optimise the last mile delivery for product components necessary for the local production process. These deliveries can be performed with autonomous vehicles and drones. The location of facilities in the city will also force companies and their logistics to be more environmental friendly and more resource efficient too.

13.1 Specific Challenges for USC

A set of specific challenges related to the features of this strategy is here reported representing the gaps to be covered with innovative approaches and tools as from the RITs in the following section.

1. *Coping with the constantly changing urban context:* the focus is on small-scale manufacturing. Several constraints due to this specific context must be tackled and this leads to define several technological challenges. It is essential to be able to integrate the production and manufacturing into the urban web characterised by the increase of smart cities infrastructures. City logistics need to be optimised to efficiently implement last mile transportation and delivery.
2. *Optimise circulation of flows among different and inter-connected urban areas;* it will constitute another challenge due to issues such as traffic jam at the city entrance, overcapacity of some axis of circulation, local pollution (within port areas for instance) etc. Being able to move people and goods from one urban area to another in an efficient and sustainable way would thus be essential to promote integration.
3. *New user needs due to development and transformation of the urban web*: to understand them, it will be necessary to collect and analyze with proper tools a significant amount of data. The generated information will enable to build up and quickly reconfigure flexible networks and production lines to fully answer to the ever changing customer needs.
4. *Managing new entrepreneurial generation:* the technological transformation and the massive adoption of digitalisation will lead to a full transformation of the workforce This will impact the training and the ambition of the new generation,

which will apprehend the technological transformation as an opportunity to reach their own goals and to provide a service or a product to the society. It is necessary to create an environment that can facilitate the creation of start-ups and fab-lab as a way for spread innovation.

13.2 Research and Innovation Topics for USC

The most important research and innovation topics for the USC strategy are here described.

RIT.1: Evaluating SC impacts on urban context

Citizens, policy makers and entrepreneurs need to efficiently measure the immediate, long-term, direct and indirect impact of any new urban manufacturing implementation which will be settled within their local urban context. Due to the complexity of this kind of environment, it is essential to consider multiple perspectives (e.g. energy consumption, pollution, noise, overload etc.). Research will have to focus on the development of a new tool taking into account all the necessary KPIs linked to these different perspectives and which comply with European priorities in urban areas. Among them, it is important to consider Greenhouse Gases (GHG) emissions (direct and indirect) and other kind of pollution (rejection of pollutants, chemicals, waste generation etc.), space availability, and noise generation. All the types of data previously mentioned could be monitored and acquired via different systems. However, due to the different types of measurements, the tool must integrate several data sources spread across the city to gather real-time data and to provide different visualisation options, through a user-friendly interface. Possibility of creating different stakeholder profiles will be enabled by the tool, encompassing all kind of audiences composing the local urban context, (e.g. citizens, policy makers, entrepreneurs) to customise the use of the tool. All data have to be publicly available on a platform dedicated to the local urban context, where citizens can then take part in the discussions. The availability of all data collected and processed will lead to more informed decisions enabling each stakeholder category to accurately monitor the potential impact on the urban context. Such a solution will permit the setup of consensus among the stakeholders and decisions will be taken on real data.

RIT.2: New approaches for smart distribution in smart cities: optimisation of city logistics and of shared transportation platforms

In the urban context, distribution and last mile delivery have still to be optimised. The efficiency rate remains low and causes different issues such as lack of organisation, traffic congestion, high energy consumption, multiplication of commutes etc. In the meantime, the creation of centralised distribution centres and adapted logistics for smart cities is essential in order to implement last-mile transportation efficiently and assure distribution of materials and components. A set of different issues has to be explored like:

- City logistics and the last mile delivery trigger different issues requiring flexible solutions. Investigating the feasibility of modular systems and their implementation within the urban web should provide an alternative to the present transport system. Moreover, rail, metro and light rail systems must be envisaged as a solution to be fully exploited and the organisation of last mile delivery circuits could benefit also by using for example, automatic sorting systems directly implemented in the trucks. Collaborative solutions to manage unexpected issues (alternative itinerary in case of a road accident, maintenance anticipation, recalculation in case of a vehicle break down etc.) have also to be developed under ad hoc integration of the SC participants.
- Innovative ways of distribution (coupling trucks and drone, optimisation of delivery routes in real time, light rail systems, combining technologies etc.) in order to get a higher efficiency rate. Resource efficiency and optimisation of the loads will be among the main priorities. Another possibility to find new ways of sharing transportation and distribution is to explore how different transportation platforms are able to share their capacity. The adoption of these platforms would enable the possibility of tuning and fully optimising the existing load capacity, leading to additional delivery options.

RIT.3: Networked modular facilities and technologies for local manufacturing.

Due to automation and advancements in additive manufacturing technologies, the development and implementation of modular facilities represent an enabler for the relocation of small manufacturing sites within urban areas. In particular, building up smart and modular facilities easily and quickly adaptable to product specifications, as required by the final end users, is essential to support the product customisation and of "fast ordered-fast delivered" trends. Automation of most of the tasks can speed up order customisation. It is important to study new models for sharing these design and production facilities among different industries (for instance by using gate fees). Facilities should hence be reconfigurable and interoperable for different types of orders and products. Production lines and related logistics systems do not form one large rigid process anymore, but rather are composed of multiple modular islands, easily reconfigurable via suitable data sets available for the product requirements. The modular facilities should be adaptable to each local context, and, as far as possible with the lowest carbon footprint. The creation of new Fab-Labs will further improve the democratic adoption of technologies and their widespread use. Due to the assertion of the DIY trend, small and medium scale plants provided with manufacturing solutions can relate to service centres, to directly support the final customer in the stage of production or assembly of the specific and personalised product. Production capacities, prediction of lead times and flexibility are of first importance to deal with the expectations of end users. These modular facilities have to be easily accessible and possibly movable from one location to another. The implementation of platforms can enable an easier and shared management of these facilities both for Business to Business (B2B) and Business to Consumer (B2C) purposes. Online platforms can also support centralised sourcing for multiple DIY manufacturers in the urban area. The smart city context needs to be designed to support the development of this model and its connection to the surroundings.

RIT.4: Autonomous transportation systems in urban manufacturing and rise of awareness for their acceptability

Autonomous systems are considered as the next transport revolution for both people and goods. The adoption of autonomous transport in the urban context raises several research issues. The first regards the coexistence of autonomous and non-autonomous vehicles and public reaction towards the increasing number of autonomous vehicles in the different flows, re-characterizing the urban concept. A full study (including use of drones for delivery purposes) is required to establish an action plan for a step by step integration of autonomous vehicles within the urban context, taking into account the growing number of charging stations needed for the electric vehicles, which is closely linked to the increasing electrification of all processes. In this research, it is important to consider awareness from both perspectives: (i) people aware of sharing their space with autonomous vehicles and (ii) autonomous vehicles aware of the presence of non-autonomous vehicles around them. Fleet management processes require significant updates with the emergence of electric, autonomous and new types of vehicles. Coupling electric/autonomous trucks with drones for delivery purposes will render most of current processes obsolete. Consequences on fleet management and new methods for optimisation must be analysed and developed. Further research on autonomous light rail and autonomous metro systems have also to be considered due to their ability to move freight (not only passengers) with no Greenhouse Gasses (GHG) emission. Coordination of the different flows composing the urban context is also necessary. Analysing new modes of transport to tackle this challenge represent an option (for instance, coupling of autonomous trucks and drones for goods deliveries, aggregated modes of transportation, etc.) to be explored.

13.3 Impact

The innovation path identified with the RITs can have significant impacts on SC performance. The future impacts expected from the development of the RITs for the USC strategy include:

- Increase of environmental sustainability and reduction of GHG emissions
- Improve of logistics agility
- Reduction of the lead times for goods and processes
- Decrease of transport time for goods and people
- Increase in the use of new transport systems
- Increase of resilience of the urban transportation
- Increase of transparency of decision making process for urban planning.

14 Conclusions

This chapter presented technology roadmapping process that brought to the definition of 10 SC strategies and related RITs. Specific paths in the medium/long term are proposed in terms of contextual features, main challenges and specific lines of intervention, i.e. the RITs, with proposed solutions and enabling technologies for the full implementation of each strategy.

This work formalizes knowledge for previous studies with the support of external experts proposing a path based not only on technological development but also on new organisation models where the role of each actor in the SC is enhanced by innovative ways of collaboration. From the managerial point of view, this work proposes some paths supporting the decision-making process and each company can choose one or a combination of SC strategies taking into consideration the possible interdependency and complementarity.

In order to assign the 10 SC strategies to the three categories of innovation defined in Sect. 3 (i.e. trend setting SC, advancing SC, revamping SC), a brief description of each strategy is provided, underlining the peculiarities that influence their intrinsic level of innovation. In particular, the trend setting SC strategies, including novel and highly innovative ones not yet applied in a wide manner, imply radical changes at process, network and technological level:

- ***Biointelligent SC***. Biointelligent principles and systems employ nature-identical and nature-analogue processes and technologies to improve production and communication for an efficient value creation. The aim is to employ SC processes and services in a customizable and self-organising manner, changing the way companies network with others by imitating and assimilating processes within nature and thus to improve efficiency.
- ***Human centred SC***. Given the specific challenges arising from demographic and social trends as well as the specific needs of each categories of workers, the aim of this strategy is the conception and development of SCs enabling the inclusion of people and the valorisation of their skills, in order to contribute to employee satisfaction and well-being changing the way business processes are organised and creating new networking structures.
- ***Hyper-Connected SC.*** It is expected that in this SC, digitalisation is fully implemented and entities share real-time information through advanced digital platforms to communicate, monitor and manage activities thanks to connected nodes (like machines, products, factories, vehicles). All nodes are vertically integrated, as well as product lifecycle and inter-company value chain are horizontally integrated to allow the optimisation of the SC operations in smart environments.

Concerning the *advancing SC strategies* including ones already applied but only partially spread in industry due to the need to innovate some processes and to implement radical changes at technological and network level:

- ***Closed Loop SC***. It aims to integrate forward and reverse supply chain operations to support flows of product, components and other materials, such as by-products and waste. Part of the Closed-loop strategies are already implemented but waste management process to cover the entire product life cycle from cradle to grave are still in the need to further invest in research.

- ***Customer-driven SC***. It orchestrates every element of supply to satisfy demand wherever it occurs. Each decision along the SC has to be driven by customer's needs, expressing their own singularity in terms of products and services. A key element is to anticipate customer demand reacting efficiently to an unstable and unpredictable demand according to an agile approach.
- ***Disaster Relief***. It is employed when disruptions (which can be either man-made or natural) affect society and business, threatening its objectives and needs, and impact on companies' operations. To face the first phases of the disasters, the SC operations presents non-profit objectives and NGOs, Governments and companies work together to ensure a prompt response for the first aid and then help the population in the reconstruction. In this complex environment, companies need to develop strategies to recover and prevent uncertainties and disruptions.
- ***Resource Efficient SC***. It aims to deliver greater value with less input thus reducing environmental impacts. This model contributes to the increase awareness capacity of SC partners in eco-efficient operations management practices at downstream level with the right scale of low-carbon disclosure mechanisms, ethical, responsible sourcing activities, supplier contracting and purchasing decisions at upstream level.
- ***Service-driven SC***. It entails the evolution from a product-centric to a service-centric business logic and SC, innovating from transactions to relationships, from suppliers to network partners, from elements to ecosystems. It is aimed at the establishment of an increased service orientation and the addition of services or a focused combination of goods, services, support, self-service and knowledge until reaching a service-centric structure.
- ***Urban SC***. The urban areas are characterised by high level of development, high density of people, a concentration of human structure (such as houses, commercial buildings, bridges, roads, railway), wealth, goods and services. In that prospective, Urban SC can deal mainly with the DIY paradigm and personalised production/delivery requiring local and glocal sourcing, personalised shipping. Changes in the networking structures expecially with customers and society is necessary to be put in place.

As for the *revamping SC strategies*, with well established approach where all processes and networking systems are consolidated and well known but can benefit from a radical change at technological level:

- ***Global SC***. In the global SC product and services are exchanged in a dynamic worldwide network; the multiple suppliers of raw materials and components, the decentralised manufacturing and the multimodal distribution increase the complexity of information-, material- and financial flows.

It emerged that SCs and their evolutions should be intended as complex network structures that interact with their context and the other SCs through relationships that affect (and are affected) by their strategic choices. Companies should then understand the proper combinations of the SC strategies, adapt them according to their contextual features, and self-organize in the dynamic environment in order to remain competitive. The development of specific RITs and related solutions should be targeted and complemented according to the priorities in terms of performance and impacts. Further efforts should be done to create a structured system of assessment to help companies to evaluate the best strategies for their specific case and the needed capability to implement each RIT.

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A Journey into the European Supply Chains: Key Industries and Best Practices

Check for updates

Elena Pessot, Irene Marchiori, Andrea Zangiacomi, and Rosanna Fornasiero

Abstract Macro-trends and sectoral-specific evolutions are changing the way companies produce, distribute and build relationships in their supply network and with customers. Aiming to investigate the effective implementation of new supply chain concepts and innovation needs identified in the previous sections, this chapter provides a study of multiple cases of excellence among European supply chains. It depicts an overview of major trends and structural features of 8 key industries for European economy, i.e. Automotive, Aerospace, Fashion, Chemical, IT, Distribution/logistics, Furniture, Food and Beverage. For each industry, a structured investigation into one or more companies was performed with a total of 18 companies involved. The results identify possible matchings in relation to supply chain strategies, and good and best practices adopted accordingly.

Keywords Products and services · Sourcing · Production process · Supply chain configuration · Customer relationship · Cross-sectoral analysis · Multiple case study

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1 Introduction to Empirical Analysis of European Supply Chains

Following the analysis of the macro-trends, expected future scenarios and supply chain strategies identified as most relevant for the supply chains of the future, this chapter presents the results of an empirical exploration into current European supply chains. Specific sectoral trends, structural features, strategies, practices and implemented enabling technologies are investigated into cases of excellence that can be considered as a reference point for manufacturing, process and logistics sectors.

The study aims to carry out a holistic and contextualised research to further inform the 10 supply chain strategies identified, i.e. Hyper-Connected Supply Chain (HCSC), Disaster Relief Supply Chain (DRSC), Global Supply Chain (GSC), Urban Supply Chain (USC), Resource Efficient Supply Chain (RESC), Human centred Supply Chain (HSC), Closed Loop Supply Chain (CLSC), Customer Driven Supply Chain (CDSC), Service Driven Supply Chain (SDSC), Biointelligent Supply Chain (BIOSC). A multiple case study (Yin 2013) was performed and guided by the following research questions:

1. *How are successful European supply chains shaping the way they produce, distribute and build relationships in their supply network and with customers in order to remain competitive at global level?*
2. *What practices should be considered to successfully develop one (or more) supply chain strategy among the ones identified as most relevant for the supply chains of the future?*

Sectors and industries considered as reference in the European competitive landscape were firstly analysed. Specifically, 8 key industries of European economy were selected, i.e. Automotive, Aerospace, Fashion, Chemical, IT, Distribution/logistics, Furniture, Food and Beverage. These sectors were selected as they demonstrate having large and complex supply chains (in terms of number of echelons and actors involved, and interdependencies with other key European sectors) and unique and complementary features to provide insights into general trends across European and global economy (International Labour Organization 2016). Moreover, they are recognised among more volatile, uncertain, complex and ambiguous (VUCA) operating environments and affected by higher requirements by customers (Roland Berger 2015) and they have been included in the "Internal Market, Industry, Entrepreneurship and SMEs" area of intervention of European Commission. Table 1 summarises the key figures of the 8 industries selected.

Per each sector or industry, one or more case studies were selected in order to obtain a broad overview of the current evolution and successful patterns of practices developed by European supply chains. The 18 companies selected within the 8 industries demonstrate to be sufficiently heterogeneous (Yin 2013) in terms of size, role in the supply chain, and main areas of excellence (i.e. successful practices in different supply chain dimensions). Specifically, the supply chain dimensions considered were the following: Products and services, Sourcing, Production process, Supply chain

Table 1 Relevant European industries selected in the study

Industries	Turnover	Workforce	Export	Sources
Automotive[a]	€1,050 billion ($1174.88 billion)	13.3 million workers	€138.6 billion	ACEA (2018, 2019)
Aerospace[b]	€117 billion (aero) €7.2 billion (space)	540,000 workers (aero) 40,000 workers (space)	€81 billion (aero)	AeroSpace and Defence Industries Association of Europe (2018)
Fashion[b]	€181 billion (textile and clothing)	1.7 million workers	€141.8 billion (clothes and footwear)	Eurostat (2018), EURATEX (2017)
Chemical[a]	€529.5 billion	1.14 million workers	€149.9 billion	CEFIC (2018)
IT[b]	€362 billion ($400 billion)	5.8 million workers	€340 billion	Eurostat (2018), Atomico (2018)
Distribution/logistics[b]	€1,576 billion (storage and transport)	10.3 million workers	/	Eurostat (2017)
Furniture[c]	€96 billion	1 million workers	€15.1 billion	EFIC (2019)
Food and Beverage[c]	€1.19 billion	4.57 million workers	€110 billion	Eurostat (2019), FoodDrinkEurope (2019a)

[a]in 2018, [b]in 2017, [c]in 2016

configuration (transportation, distribution and warehouse management), Customer relationship. Table 2 presents an overview of the 18 case studies. For reasons of confidentiality the case names have been anonymised and will appear in Italics.

The empirical inquiry involved collection of data from multiple sources, whilst enabling triangulation and reducing possible bias (Yin 2013). Specifically, several publicly available reports and documents were considered for sectoral analysis. The case studies involved semi-structured interviews conducted with key managers (strategic or operational) of supply chain management, operations and logistics areas, and integrated with publicly available data from press reviews, websites and official company documents.

This chapter is structured as follows. Sections 2–9 summarise the main features of each sector in terms of importance, typical supply chain structure (number, type and location of main actors), and main trends characterising the sector dynamics. Dedicated text boxes present briefly the key figures (e.g. turnover and market competitiveness), the structure of the supply chain, and the main practices of the cases selected in each industry.

Section 10 depicts the cross-sectoral analysis, with evidence of commonalities and differences in trends and relevant practices and performance; Sect. 11 presents the results of the cross-case analysis. Specifically, possible matchings were identified

Table 2 Overview of companies selected in the study

Cases	Location (Country)	Role in the supply chain	Distinctiveness
Automotive			
SupplyWheels	Milan (IT)	First tier supplier of OEMs (car manufacturers)	Leader and pioneer in tailor-made, high segment car tyres
AutoSupply	Lippstadt (DE)	First tier supplier of OEMs (car manufacturers)	Worldwide market leader for climate control and thermal management for automotive industry
Aerospace			
FlyParts.Inc	Alverca (PT)	First tier supplier of OEMs (aeronautics manufacturers)	Long-term, well-established, global supply chain focused on aeronautics manufacturing and Maintenance, Repair and Overhaul (MRO) services
Fashion			
FashionDesign	Vicenza (IT)	Designer and manufacturer	Specialized in R&D, engineering and operations management of a range of exclusive fashion brands
EyewearSupply	Pordenone (IT)	Manufacturer and distributor	Leader in the marketing of ophthalmic and solar lenses with high level of personalized services
FashionOnline	London (UK)	Distributor and retailer	Pioneer and world leader online luxury fashion retail platform. Ex unicorn start-up company
SportShoes	Montebelluna (IT)	Designer and manufacturer	Specialization in personalized sportswear production
Chemical			
ChemVariety	Dusseldorf (DE)	Manufacturer, distributor, retailer	Multinational company with leading brands and technologies in 3 business areas: beauty, homecare and adhesive

(continued)

Table 2 (continued)

Cases	Location (Country)	Role in the supply chain	Distinctiveness
ConsGoodsLead	Cincinnati (US)	Manufacturer and distributor	Multinational corporation with superior market performance into several segments of Fast Moving Consumer Goods (FMCG?)
IT			
LeadTech	New York (US), Portsmouth (UK)	Service/technology provider	Globally-integrated enterprise leader in the IT market
DigitalSCProvider	Walldorf (DE)	Supply Chain Software provider	Second global market leader in the Enterprise Application Software (EAS) market
FinanceTech	Birmingham (UK)	Service/technology provider	Supplier finance technology platform for both SMEs and banks and corporates
Distribution/logistics			
LogisticService	Pedrola (SP)	Distributor/logistics operator	Group among the European logistics operators with the major international transport flows and expansion rate
Furniture			
FurnitureForYou	Delft (NL)	Manufacturer	Worldwide leader in the ready-to-assemble, well-designed and affordable home furniture
CarveSupply	Treviso (IT)	First tier supplier	One of the biggest manufacturers of furniture components and kits worldwide
Food and Beverage			
MealsOnWheels	Maia (PT)	Distributor and retailer	Food retail leader in the Portuguese market
FoodPrepare	Maia (PT)	First tier supplier	One of the top companies specialized in food processing (preparations)
PetfoodProducer	L'Hospitalet de Llobregat (SP)	Manufacturer	One of the leading companies in the manufacture of animal food products

between case studies and supply chain strategies, i.e. which companies (and related supply network) are developing (or are planning to develop) a specific supply chain strategy, or which practices performed by the companies can be linked with the core features of the supply chain strategies identified in Fornasiero et al. (2020).

2 The Supply Chain of the Automotive Industry

The Automotive industry is crucial for Europe's prosperity due to its impact on employment and overall economy (contributing to 6.8% of EU GDP, and generating a trade surplus of €90.3 billion), and the important multiplier effect in the upstream industries (e.g. steel, chemicals, and textiles), as well as downstream industries (e.g. ICT, repair, and mobility services) (European Commission 2019a).

The main products include: vehicles carrying passengers, vehicles carrying goods, 2- and 3-wheel vehicles and quadricycles (e.g. motorcycles, mopeds, quads, and minicars), agricultural and forestry tractors and their trailers (European Commission 2019a).

The industry is quite fragmented and structured around different tiers, with the leading Original Equipment Manufacturers (OEMs) contracting with a limited number of mainly Tier 1 suppliers for between 4,000 and 9,000 different components contained in a vehicle platform. In the EU, there are 227 automobile assembly and production plants, with a total number of 304 manufacturers in EU27 (ACEA 2018); the number of manufacturers of motor vehicles, trailers and semi-trailers (including various parts and accessories) is 20,161 (Eurostat 2017).

The industry is mainly constituted by mid-sized enterprises. In addition, several EU OEMs (e.g. Renault, BMW and Volkswagen) belong to the worldwide top list of the 2,500 biggest enterprises in Automobiles and Parts (Konrad and Stagl 2018) and have the highest shares of electric powertrain technology patents (Fredriksson et al. 2018).

Nowadays, the industry is shifting to new business models and new technologies (as data-enabled services as alternative powertrains) driven by technological trends as autonomous driving through Artificial Intelligence and connectivity, electrification and shared mobility, in addition to an increasing supply chain sourcing complexity and collaboration due to globalization and sustainability concerns.

CASE STUDY *SupplyWheels*

SupplyWheels is a leader and a pioneer in Europe in the production of tailor-made car tyres. It is world widely recognised as a premium brand, with a turnover of about €5.2 billion (2018) and around 31,500 employees. Its supply chain comprises a global supply base, 19 production plants in 12 countries and a commercial presence in over 160 countries, with 15,900 points of sales.

SupplyWheels is mainly pursuing a **Closed Loop supply chain (CLSC) strategy**. The company has a very high level of commitment in the environmental, social and economic pillars of sustainability and collaborative mechanisms to reach them. As part of its sourcing strategy, the company has fixed very high and restricted parameters for supplier selection in terms of compliance to high ethical and environmental standards. A supplier handbook has been designed to verify adherence with company principles and values, conduct and managerial approach. In addition, a Supplier Sustainability Audit is regularly commissioned to sector leading companies, and a Supplier Award is assigned each year to suppliers excelling in environmental and social sustainability through technological innovation.
SupplyWheels pursues a Green Sourcing Policy that seeks to promote and incentivise environmental awareness in the overall supply chain, by investing in the tracking, collection, treatment, and transfer into new products for the reuse, recovery and recycle of discarded and end of life tyres.

CASE STUDY *AutoSupply*
AutoSupply is one of the world's leading companies in the area of control panels for the Automotive industry, with a turnover of more than €500 million and over 2,500 employees. It builds partnership-based and long-term cooperation with almost 150 suppliers worldwide and ensures excellent customer service to approximately 30 customers.
AutoSupply is mainly pursuing a **Global supply chain (GSC) strategy**. The overall supply chain is challenged by global trends as the integration of new technologies and innovative materials in the final products. The partnerships in the upstream supply chain leverage capacity agreements and data exchange for guaranteeing tracking and ensuring safety stocks for delivery (replacement period) and quality problems. The cooperation in the downstream supply chain is supported by the increased adoption of blockchain and mobile apps with global logistic providers to better respond to customer requests.

3 The Supply Chain of the Aerospace Industry

The European Aerospace industry contributes to 4.1% of EU GDP with the development and manufacture of aircrafts, helicopters, drones, aero-engines, other systems and equipment. This analysis specifically considers the Civil Aeronautics and Civil Space sub-sectors of Aerospace.

The industry comprises over 3,000 SMEs in Europe, operating in the three main pillars of air framers, engine and equipment manufacturers, and systems manufacturers (AeroSpace and Defence Industries Association of Europe 2018). There are on average three tiers of suppliers providing a broad product line (parts) for the flight vehicles provided to the customers, i.e. airlines companies, states, etc.

The Aerospace supply chain is characterised by a high level of product and supply chain complexity, with large-scale data requirements and the need of extensive expertise for running rate simulation tools and multiple enterprise resource planning systems aimed at ensuring visibility and efficiency along the multi-tier supply chain (Cheater 2017). Companies are then shifting from traditional approaches to new business models and the introduction of digital technologies in all business areas, including digital shop floor, demand sensing, smart procurement and logistics, real-time information sharing platforms, smart products and services (Miller 2018). Aerospace is the largest single industry using additive manufacturing for the production of lightweight parts with complex geometry and small aerostructure components (Roland Berger 2017). Most innovative strategies include risk-and-revenue-sharing business models, also changing the relationship between the OEMs and their suppliers, and the substantial introduction of maintenance services charged by flight-hours and nose-to-tail service in the OEMs' offer.

CASE STUDY *FlyParts.Inc*

FlyParts.Inc is one of the leading and oldest aeronautics companies in the world, manufacturing aeronautics parts and providing Maintenance, Repair and Overhaul (MRO) services, with a turnover of €203 million (2018) and more than 1,900 employees. It has about 70 clients in 40 countries, served by one production plant with 10 maintenance hangars and 1 large engine overhaul shop.

FlyParts.Inc is mainly pursuing a **Service-driven supply chain (SDSC) strategy**. Well-recognised for experience and reputation, *FlyParts.Inc* relies on strong relationships with partners, promoting a collaborative supply chain with long-term contracts, a dedicated procurement and inventory management and a strong compliance program with its suppliers. The company is constantly expanding its MRO services portfolio and investing to reduce stocks in maintenance units thanks also to more efficient and faster logistics and transportation.

4 The Supply Chain of the Fashion Industry

The European Fashion industry contributes to the 3% share of value added and 6% share of employment on EU manufacturing (European Commission 2015a, b). It is characterised by a tremendous variety of products into several specific subsectors that include Apparel, Textiles, Fabrics, Footwear, Accessories, Watches and Jewellery, Luggage.

There are 176,354 manufacturers of textile and clothing in the EU: the clothing industry has the largest number of companies, estimated 119,343 in 2017 (Statista 2017); the European Footwear sector is represented by 21,000 companies (European Confederation of the Footwear Industry 2018); the European leather industry counts over 3,000 companies (Cotance 2018). European fashion brands are world leaders, and each tier of the production chain is present in Europe (EURATEX 2017). SMEs account for more than 90% of the workforce and produce almost 60% of the value added; they are mainly niche players focusing on quality, innovation, creativity and outstanding customer service (EURATEX 2017).

Several trends are disrupting the Fashion industry, including: the decline of brick-and-mortar stores and traditional retailers in favour of online platforms and "unified commerce" (i.e. fusing physical and digital stores and integrating activities in a centralised (IT) infrastructure); omnichannel strategies and investments in Direct-to-Consumer (D2C) sales; the social, environmental and economic responsibility becoming the "new quality"; the moving of major brands towards towards "total look" and "storytelling" (i.e. emotional involvement in the brand, also thanks the involvement of fashion bloggers) to respond to savvy, sophisticated and purposeful consumers (CBI 2016; McKinsey Apparel, Fashion & Luxury Group 2018).

CASE STUDY *FashionDesign*

FashionDesign is the leather goods and footwear division of a fashion group, managing the design and production of all the shoes and bags of the various brands of the group. Specifically, the company has 96 employees and a global turnover of €280 million in the wholesale/retail channel. The supply chain includes 50 suppliers of raw materials, 60 production plants (contractors)—partly collaborating in product innovation, thanks to adoption of 3D tools for co-design—mainly based in Italy, and worldwide commercial branches.

FashionDesign is mainly pursuing a **Global supply chain (GSC) strategy**. It is able to combine global trends and Made in Italy into a high level of variety, covering a market positioning of products from the mass-market segment up to the luxury, with an international distribution outreach that changes configuration according to produced products. The use of RFID allows the traceability of the products along the overall supply network, avoiding also counterfeiting. The company is committed to transparent and sustainable business practices across the entire group.

CASE STUDY *EyewearSupply*

EyewearSupply is an Italian medium enterprise in the eyewear industry producing and marketing finished and semi-finished lenses (and recently also frames), with revenues of €53 million and more than 100 employees in the only production site. The company daily serves more than 600 wholesalers and optical laboratories across the world and leverages on a total of 40 suppliers worldwide.

EyewearSupply is mainly pursuing a **Global supply chain (GSC) strategy**. The supply chain is very long and globally distributed, but *EyewearSupply* relies on collaborative relationships and coordination mechanisms built on trust, mutual economic advantage and technological support (e.g. for coordinated planning of worldwide deliveries) that help in overcoming the informative and cultural gaps with global partners. A trade-off between efficiency and flexibility is reached thanks to a balanced level of automation for both production lines and outbound logistics, the adoption of optimisation models for inventory and transportation loading, and a strategy of stock sharing with customers. This ensures high reliability in terms of service level, dynamicity in adapting to customer requests, and tailored services.

CASE STUDY FashionOnline

FashionOnline is an English e-commerce business platform in the high-luxury Fashion industry, with around 3,200 employees worldwide and revenues of €543.3 million in 2018. It has established partnerships with a worldwide supply base including 614 world leading luxury retailers and 375 brands, and delivers a large portfolio of luxury fashion items in more than 190 countries.

FashionOnline is mainly pursuing a **Hyper-Connected supply chain (HCSC) strategy**. It offers a powerful 4PL Supply Chain platform for real-time data sharing, monitoring and tracking from product and content creation to global fulfilment network in integration with its partners.

The company sets up measures for protection of personal data, privacy and information security of final customers. Data are collected from and used by multiple touch points in the luxury fashion ecosystem, and enable relevant personalised services as last mile logistics, better estimate delivery times for a seamless buying experience, and tailor marketing and advertising thanks to sophisticated and autonomous Artificial Intelligence and Machine Learning algorithms.

CASE STUDY *SportShoes*

SportShoes is an Italian company of the Montebelluna footwear district, specialized in the production of sportswear (especially cycling and snowboarding), with a turnover of around €25 million in 2017. The supply chain consists of 20 different suppliers, mainly located in Asia; top-of-the-line items are developed at the Italian headquarter, with selected materials exclusively from artisanal "Made in Italy" processes. The downstream network is divided into a direct (Italy and Germany) and an indirect market, with 102 distribution companies worldwide.

SportShoes is mainly pursuing a **Customer Driven supply chain (CDSC) strategy**. Products are mainly customised based on specific requirements of customers, with development of ad hoc prototypes of new models of shoes and clothing with 3D printing systems, and all the decisions regarding sourcing and production are determined by a production model completely driven by consumer's demand and needs. The customer experience starts from the selection of materials to the personalised distribution and the after-sale services that guarantee the replacement/repair of products during the use by customers.

5 The Supply Chain of the Chemical Industry

The European Chemical industry is among the most consolidated and accounts for 1.1% share of value added and 7.3% share of employment on EU manufacturing (Eurostat 2019).

Chemical products are used in making 95% of all goods, and they can be subdivided in three main categories: base chemicals (petrochemicals; polymers, and basic inorganic), specialty chemicals (including agricultural chemicals) and consumer chemicals.

Europe is the 2nd largest chemicals producer in the world, with a share of 15.6% in total sales. Although the majority of supply chain activities are on global level, the EU Member States account for 50% of global chemicals trade, with 30% of exports going to non-EU countries. The number of European chemicals manufacturers in the EU is 28,329, with 95% of them employing fewer than 250 staff members (CEFIC 2017).

Main supply chain actors are substance producers and formulators of preparations, industrial chemical users, distributors. In Europe, the main factors affecting the competitiveness of the chemical industry are the energy costs, the EU regulation costs, the levelled consumption due to the end markets' trends, the merging and acquisition resulting in the creation of giant companies, the shift of chemicals manufacturing to Asia, the introduction of technologies such as real-time analytics and automated control actions towards Chemicals 4.0 (CEFIC 2018).

CASE STUDY *ChemVariety*

ChemVariety is a German company from the Chemical industry with an international outreach in three different sectors corresponding to the Business Units (BU) of beauty, laundry and home care, adhesive technologies. It has more than 53,000 employees and a turnover of more than €20 million for 2018. The supply chain is centralised geographically, with the sourcing process fully leveraged across BUs, but the production activities in the more than 180 production plants are contextualised according to geographic, economic and political features.

ChemVariety is mainly pursuing a **Global supply chain (GSC) strategy**. The scale-up of technological solutions across functions, regions and BUs allows to optimize both costs and fulfilment of local needs. The company leverages a common IT system for real time monitoring, tracking and traceability along the supply chain; a common Industry 4.0 strategy to integrate IoT, automation, robotics, analytics and related training in the production, and nearfield technologies and drones in logistics; data collection through different channels, as platforms and social media, to better understand needs and issues of the final customers across BUs. All the plants are pursuing sustainability with reduction of emissions, water use and waste volumes, and adoption of recycled materials packaging.

CASE STUDY *ConsGoodsLead*

ConsGoodsLead is one of the world's largest consumer goods companies, with more than 92,000 employees worldwide and reported revenues of more than $ 66.8 million in 2018. The globally distributed supply chain comprises more than 100 suppliers and has a commercial presence in over 180 countries.

ConsGoodsLead is mainly pursuing a **Resource Efficient supply chain (RESC) strategy**. The supply chain is organised to realise scale advantages across the several business operations by the adoption of co-location strategy with suppliers (manufacturing operations closed to raw materials), and a data-driven approach for sourcing strategy. The distribution network leverages a centralised data platform for warehouses and transportation management, which comprises the co-loading with competitors and cost-sharing for customer shipments. This helps to optimise trucks vehicles fill/loading rates by also using inter-modal and multi-modal logistics agreements. In addition, a common supply chain finance system allows to gain operational synergies.

ConsGoodsLead shares along the overall supply chain science-based sustainability targets for reducing impacts and accordingly lean-and-green practices.

6 The Supply Chain of the IT Industry

The European IT industry contributes to the 4.8% of the European economy and has grown 500% in the last five years as economies, jobs and personal lives are becoming more digital, connected and automated, with an estimated grow at a rate of 5% (Certification Europe 2019).

The IT industry comprises companies that produce software, hardware, semiconductor equipment and companies that provide internet and related services such as Google, Apple, Facebook, Cisco, IBM and Intel (ITI 2019; CompTIA 2019), including blockchain and security. The IT supply chain has among the most complex structures, especially due to the high degree of outsourcing of activities to design firms, consultancy firms and contract manufacturers.

There are 17 European tech companies that surpassed the over $1 billion milestone in 2018, and Europe is now consistently producing companies exceeding $5 billion in value, also thanks to the presence of more than 180 tech hubs across the territory (Atomico 2018).

Main trends affecting the industry, resulting in increasing investments in capabilities and security, include: the emerging tech categories, the need to be compliant with security regulation (e.g. European Union's General Data Protection Regulation (GDPR)), the cybersecurity, the shifting to strategic IT alongside business units (CompTIA 2019; Deloitte 2019).

CASE STUDY *LeadTech*

LeadTech is a global leader in the information technology market, providing software, innovative technologies and consulting solutions, with a turnover

of about $80 billion in 2018 and around 360,000 employees. It has a global presence and operates in more than 175 countries.
LeadTech is mainly pursuing a **Customer Driven supply chain (CDSC) strategy**. *LeadTech* provides consultancy and innovative technologies and creates solutions targeted on the needs of their clients and also co-created with them. It supports the customers in learning to control relationships across the supply chain and gaining knowledge about the whole supply chain through information exchange point-to-point to achieve agility, reduce costs and risks, modernise their operations, innovate and achieve a secure infrastructure. Specifically, it focuses on the implementation of blockchain technology in achieving increased collaboration and visibility across the supply chain.

CASE STUDY *DigitalSCProvider*
DigitalSCProvider is a provider of enterprise application software headquartered in Germany, with worldwide revenues of €24.7 million. It leverages on a network comprising of more than 13,000 partners to provide end-to-end, industry-specific solutions to 25 industries and 12 business lines.
DigitalSCProvider is mainly pursuing a **Human centred supply chain (HSC) strategy**. The company grounds its vision on the concept of 'intelligent enterprise' and 'augmented human intelligence' guiding the overall supply chain strategy of its customers. Specifically, it supports the development of IoT in manufacturing operations, inter-robot orchestration and machine-to-machine feedback systems to increase the visibility of manufacturing operations, integrated with the attention towards understanding the impacts of digitalization on workers' capabilities, employment and changes in educational models for enhancing better working environments.

CASE STUDY *FinanceTech*
FinanceTech is a software company that provides and operates a finance technology platform for supplier early payments solutions, with targeted invoice finance solutions. It is a small company with a turnover of £12.3 million in 2018, mainly deriving from the public sector. It sits in the middle of three different actors, i.e. buyers, suppliers and investors, to provide an innovative invoice financing model for supply chain value.

FinanceTech is mainly pursuing a **Service Driven supply chain (SDSC) strategy**. The developed technology enhances avoiding risks and problems along the supply chain as limited cash flows and late invoice payments with targeted invoice finance solutions. The company keeps innovating the platform with cross border and cross currency supply chain flows in order to grow the offered services across multiple countries and currencies.

7 The Supply Chain of the Distribution/Logistics Industry

The European Distribution/logistics industry is rapidly developing and one of the largest in the EU, with 10.3 million workers (Eurostat 2017) and a share of 9.7% on the GDP. The main services include internal transport (from arrival to the warehouse or from final assembly to shipping), external transport (between two sites or from supplier to customer), warehousing, packaging, value added services (such as custom packaging, assembly or data management and information management).

The number of transport and storage enterprises in the EU 2017 is 1,246,259 (Eurostat 2017). They are mainly SMEs, with an aggregate of 9.1 employees and mainly focused on road transport, while the bigger enterprises offer railway, air, sea and road transport (European Commission 2015a, b).

Main trends shaping the European logistics industry are: the shifts in international trades due to free trade agreements or trade wars; the process changes driven by the introduction of automation, robotics, Artificial Intelligence, Internet of Things (IoT) and Blockchain; the development of innovative last-mile delivery by using autonomous drones and vehicles; the electric mobility advancements and transport machine technology developments (DHL 2018; PwC 2019).

CASE STUDY *LogisticService*

LogisticService is a logistics operator delivering supply, transport, storage, and distribution services, with a group-level turnover of almost €160 million and a total of 1,100 employees. Its supply chain comprises more than 800 suppliers of transport fleets and a total of 7 warehouses.

LogisticService is mainly pursuing a **Service Driven supply chain (SDSC) strategy**. The company guarantees the full traceability of service as key objective to be accomplished in integration with the customers' tools and adopts advanced data analytics (i.e. positioning and utilisation of the entire fleet) for supporting decision-making in service delivery and enhancing customer competitiveness. *LogisticService* has established collaborative relationships with its customers, working together in projects to optimise routes and decision-making based on business intelligence and the adoption of apps to control the supply chain, and recently introducing last mile distribution and multimodal transportation to answer their requests.

8 The Supply Chain of the Furniture Industry

The European Furniture industry is labour-intensive and highly export-oriented, especially inside Europe. It employs around 1 million workers in 130,000 companies, most of them SMEs and micro firms (EFIC 2019).

The main products include household (domestic) furniture, office and institutional furniture, furniture related products and other semi-finished and component products.

The European Furniture supply chain is spread in all the territory and consists of four major components: suppliers, manufactures/producers, retailers and consumers. It can be configured by destination (office furniture, kitchen and bathroom furniture, dining, living and bedroom furniture), by components type (bars, cabinet doors, drawers, frames, worktops, others), by support material (wood, MDF, particle board, plywood, other materials), by wood species, and by coating material (veneer, melamine foils, laminates, PVC, lacquered) (Worldforniture 2019). All supply chain tiers are characterised by a high number of SMEs and the participation of some big players (highlighting IKEA, the world's largest furniture retailer).

The European Furniture sector has undergone significant changes after the worldwide crisis and important trends as: eco-design to reduce energy consumption and plan the entire products' life-cycle (including transportation) in line with the principles of the circular economy; the requests for more affordable furniture options, due to the increasing renting, and a higher diversification to address the different lifestyles and needs of customers; fast changes in design trends requiring continuous investments in innovation (CMTC 2019).

CASE STUDY *FurnitureForYou*

FurnitureForYou is a Swedish company leading the home furniture retailing industry, with a turnover of €38.8 billion in 2018 and a number of employees (defined co-workers) that is 208,000 worldwide (20,000 of them in production units). The company has 1,500 suppliers worldwide and more than 400 stores in 50 markets.

FurnitureForYou is mainly pursuing a **Human centred supply chain (HSC) strategy**. The company pay particular attention to the human factor along the supply chain. In fact, the most important KPI for the purchase agreements, fixed also in the Code of Conduct, is the safety of workers (e.g. considering the loss-time frequency due to accidents). Within production plants, beyond the investments on automatic guided vehicles and robots, the company has a strong attention towards the importance of the "soft" and human part in the change required for digital transformation (and its impacts), nurturing internal talents for reaching agility and cross-functional empowerment of workers. In the stores, operators (and customers) are supported with augmented reality tools and embedded digital touch points.

CASE STUDY *CarveSupply*
CarveSupply is one of the biggest manufacturers of components and kits for the furniture industry worldwide, with around 2000 employees and a turnover of €550 million in 2018. Its supply chain includes almost 230 suppliers worldwide and a huge logistics volume to serve the main international large-scale retail chains.
CarveSupply is mainly pursuing a **Hyper-Connected supply chain (HCSC) strategy**. The company shows a very high level of integration, leveraging on trust and transparency at logistic, informative and organisational level with both upstream and downstream supply chain, from the co-design of new products, processes and dedicated production technologies to the full traceability of the products along the logistics flows, including the packaging.
The more advanced production lines are fully automated, with collaborative robotics and a Data Exchange framework for machine-to-machine integration. While automated vehicles are adopted for internal logistics, the company is shifting to an intermodal transportation system to further consolidate/integrate the activities with the suppliers worldwide.

9 The Supply Chain of the Food and Beverage Industry

The Food and Beverage industry is the EU's biggest manufacturing sector in terms of value added, with a share of 12.1% (European Commission 2019b) and job creation, employing more than 23 million people (Eurostat 2019; FoodDrinkEurope 2019a). In half of the EU's 28 Member States, the Food and Beverage industry is the biggest employer within manufacturing (FoodDrinkEurope 2019a).

The main products of the sector in Europe are meat products, dairy products, processed fruit and vegetables, oils and fats, bakery and farinaceous products, animal feeds, fish products, grain mill and starch products, drinks (alcoholic and non-alcoholic) (FoodDrinkEurope 2019a). The supply chain comprises companies that process, pack and distribute edible goods, including fresh, prepared and packaged foods, as well as alcoholic and non-alcoholic beverages. It is characterised by a huge number of SMEs (99%) across all tiers from farms to retails and restaurants, and the participation of big players that embrace all European territory (and beyond) and respond for more than 50% of the turnover.

Driven by demographic and environmental changes that impact on food needs and connected lifestyles, main trends characterising the European Food and Beverage industry are: production and exploitation of alternative and sustainable food sources for more healthy and sustainable diets; new distribution models, such as direct to consumer distribution; adoption of IoT-connected packaging and other digital technologies as sensors and Artificial Intelligence for flexible, customized and energy-efficient infrastructures and processes; increasing offer of specific and personalized products as gluten-free ones (CB Insights 2018; FoodDrinkEurope 2019b).

CASE STUDY *MealsOnWheels*

MealsOnWheels is a Portuguese omnichannel food retailer, with more than 30,000 employees and a turnover of €4.3 billion in 2018. The supply chain comprises between 700 and 800 suppliers, mainly based in Portugal, and a total of 1,116 stores selling a large variety of products with the company's or the suppliers' brands.

MealsOnWheels is mainly pursuing an **Urban supply chain (USC) strategy**. Building on a centralised transportation and warehousing network and solid long-term procurement relationships, the company is adapting the logistics to the city with small-sized and last-mile deliveries. This is supported by the use of location technologies for real-time control, the implementation of simulation and optimisation techniques for routes and cargo space of transporting vehicles, and the adoption of different store size strategies targeted to local needs.

To reduce food waste, *MealsOnWheels* works with partners to address circularity and diversify the portfolio according to the local city needs, by transforming perishables that are not sold on a given period (but still deemed good for consuming) into other products sold by the same company, and also by collecting empty plastic packaging.

CASE STUDY *FoodPrepare*

FoodPrepare is a global group of companies focused on the design, development and supply of added value ingredients for the Food and Beverage industry, achieving a turnover of €110 million in 2018 and around 530 employees. The globally distributed supply chain includes between 400 and 500 suppliers, 8 production plants and almost 100 clients.

FoodPrepare is mainly pursuing a **Customer Driven supply chain (CDSC) strategy**. The company constantly invests in innovative capabilities and big data analytics to capture and follow the trends of the final market to produce new products and ensure high quality, on-time, flexible delivery of manufactured products for customers. Both procurement and delivery models are entirely demand-driven and optimised thanks to the adoption of digital platforms integrating the information flows with suppliers and business customers. The entire production process is digitalised and agile manufacturing enhances switches and implementation of new or different machinery and production lines according to on-time data of product characteristics. Part of the production units are close to clients, with make-to-order shipping of finished food preparations and using last-mile delivery.

CASE STUDY *PetfoodProducer*

PetfoodProducer is a multinational company of the feed animal sector, with a turnover of €620 million in 2018 and more than 1,800 employees. It has around 20,000 customers in Europe and a total of 7 production plants.

PetfoodProducer is mainly pursuing a **Resource Efficient supply chain (RESC) strategy**. The company has introduced IoT technologies to collect data, monitor the processes and stock points, and measure the footprint and wastes, both in transport and storage. It continuously re-designs its logistics network in order to optimise routes and ensure a total visibility and traceability along the supply chain with the use of a cloud based platform. Moreover, it is actively working on collaborative projects with several manufacturers to share transportation means and improve efficiency of loadings.

10 Cross-Sectoral Analysis: Main Trends and Practices

The main features and dimensions of interest of the analysed industries can be summarised as follows.

This study included both very big and top-employer industries, as the Automotive (13.3 million workers) and Distribution/logistics (10.3 million workers), and smaller ones as the Aerospace (580,000 workers). Differences in numbers are also justified by the presence of big players, as for the IT sector that includes 17 companies surpassing 1 billion of revenues and has a Gross Value Added growing five times faster than the rest of the European economy.

From the one side, all included industries are characterised by a high number of SMEs, reaching a significant percentage in Food (99% of total companies), Fashion

(99%) and Chemical (95%) industries. From the other side, many of the top players of the sector are worldwide leaders, as in the case of the Fashion and Chemical sectors.

The cross-sectorial analysis reveals also commonalities in trends and practices characterising the 8 industries. Common trends can be summarised as:

- *digitalization/adoption of enabling technologies*: e.g. in Automotive industry with electric vehicles and autonomous driving through Artificial Intelligence, and in Chemical industry with real-time analytics and automated control for energy efficiency;
- *new business models*: driven by technological advancements and/or integration of value offer, e.g. in Aerospace industry with new risk-and-revenue-sharing (between suppliers and OEMs) business models, and in Food and Beverage industry with increasing sustainable and healthy diets and climate smart and environmentally sustainable food systems;
- *new roles and structure of the supply chain*: e.g. in Aerospace industry with the increasing building of alternative supplier networks through multiple sourcing, and in Furniture industry with the reorganization of the supply chain for realizing custom elements and multifunctional pieces.

Another cross-sectorial analysis concerns the relevant practices and performance, which can be classified according to main supply chain dimensions considered in the case study analysis, including the one of sustainability. Specifically, as regards *production process*, companies belonging to different industries adopt increasing quality and safety standards and control in production and lean principles, while there are different tendencies to outsource (e.g. Aerospace), nearshoring (e.g. Fashion) and increasing partnerships (e.g. IT). In both *sourcing* and *supply chain configuration* main efforts of companies in different industries are addressed towards better synchronization, cost efficiency, flexibility and security. There are also opposite tendencies towards vertical integration (as in Fashion industry) or high levels of outsourcing (e.g. Distribution/logistics). Different practices are adopted in the *customer relationship*, regarding the inclusion into the value offer of customized products (e.g. Chemical) or with an increasing level of integrated services (e.g. Aerospace), or the need for innovation and transparency in marketplaces (e.g. Distribution/logistics).

Finally, as regards *sustainability*, we can argue that companies in the majority of industries aim to reduce environmental impacts (e.g. reduction of emissions and use of renewable/alternative energy sources) and identify solutions for adaptable, resilient and compliant supply chains.

11 Cross-Case Analysis: Supply Chain Strategies and Best Practices

This section provides an overview of the main features, commonalities and differences among the cases included in this study.

Focusing on company *dimension*, the results of the analysis show a majority of big companies (13 out of 18), as the main objective is to collect best practices from important players of European supply chains, but also SMEs (a total of 5) have been included as they constitute a significant percentage in many of the selected sectors. Focusing on the *role in the supply chain*, the selected companies belongs to both upstream and downstream supply chain, with a majority of first tier suppliers (5 out of 18) and focal companies (2 manufacturers and 3 acting both as main manufacturer and distributor), followed by service/technology provider (4 out of 18). This allows the analysis to be more comprehensive in capturing different perspectives on good and best practices for the whole supply chain.

The results also reveal that each company carries out one or a combination of the 10 supply chain strategies identified in Fornasiero et al. (2020), identifying different matchings between cases and strategies that are summarized in Table 3.

The majority of companies show the features of (or the willingness to develop) a *Global supply chain* (10 out of 18) or *Hyper-connected supply chain* (7 out of 18). This is in line with the key trends characterising all industries, i.e. globalisation and digitalisation (and enhanced connectivity). The third most adopted supply chain strategy is *Resource efficient*, revealing a key priority of pursuing efficiency along all supply chain dimensions. Finally, Service-driven supply chain (5 cases out of 18) and Customer-driven supply chain (4 cases out of 18) show the tendency to shape the supply chain according to the value offer, respectively integrating services and in terms of strict response to customers' requirements.

None of the cases seem to implement (or show the willingness to develop features of) the *Bio-intelligent* supply chain and *Disaster-relief* supply chain, but both strategies are more "futuristic" with higher requirements in terms of collaboration and technological development than the other supply chain strategies. Only one company is developing *Urban manufacturing* supply chain (*MealsOnWheels*), which is mainly linked to the concept of smart city, and adopts only some practices for urban logistics (e.g. last mile delivery) but not manufacturing. Also Closed-loop supply chain is adopted by one company (*SupplyWheels*) as it is quite difficult to implement full circularity beyond sustainability in the overall supply chain.

Finally, Table 4 summarizes the results of the cross-case analysis of the supply chain strategies described in the section above, and the practices/key points highlighted in each supply chain dimension (Products and services, Sourcing, Production process, Supply chain configuration, Customer relationship). Strategies that are mainly affected by practices identified in the cross-case analysis are also highlighted. Part of these practices were summarized in the single boxes of this section.

As the number of companies differ among the 10 supply chain strategies, the identified practices can not be attributed uniquely and incontrovertibly to a single or more

Table 3 Matching between case studies and supply chain strategies *(in bold main strategy presented in the CASE STUDY boxes)*

Industries	Cases	HCSC	DRSC	GSC	USC	RESC	HSC	CLSC	CDSC	SDSC	BIOSC
Automotive	*SupplyWheels*							**X**	X		
	AutoSupply			**X**							
Aerospace	*FlyParts.Inc*					X				**X**	
Fashion	Staff International			**X**							
	SportShoes			X					**X**		
	LTL	X		**X**							
	Farfetch	**X**								X	
Chemical	*ChemVariety*	X		**X**		X					
	ConsGoodsLead			X		**X**					
IT	IBM	X							**X**		
	DigitalSCProvider	X					**X**			X	
	Obillex			X						**X**	
Distribution / logistics	Marcotran			X						**X**	
Furniture	*FurnitureForYou*			X		X	**X**				
	Friul Intagli	**X**									
Food and Beverage	*MealsOnWheels*	X			**X**						
	Frulact					X			**X**		
	PetfoodProducer			X		**X**					
	TOTAL	7	-	10	1	6	2	1	4	5	-

Table 4 Key practices of case studies and strategies per each supply chain dimension

Key practices	Examples of practices from cases	Supply chain strategies
Products and services		
Defining products and services portfolio	• High diversity / wide assortment in product / service portfolio • On-demand / tailor-made / customer-specific solutions	HCSC GSC USC CDSC SDSC
Outlining value chain and strategy	• Focus on single product segment • Strategies and supply chain management targeted to specific products or markets	GSC RESC CDSC SDSC
Digitalization in products and services	Introduction of new technologies or new materials -> smart products or services	HCSC GSC CLSC CDSC SDSC
Sustainability in products and services	Products/services environmentally sustainable / aimed at circular economy	HCSC RESC USC
Processes supporting products and services development	• Scan of global trends and customer behaviors • Continuous investments in R&D (product, service and process innovation and related capabilities)	HCSC GSC RESC CDSC SDSC
Sourcing		
Supplier selection and evaluation	Supplier rating and selection based on trade-off among several KPIs	HCSC GSC SDSC
Defining kind of relationship with suppliers	• Different kinds of relationship with suppliers / multiple sourcing strategies • Long-term partnerships / established contracts with suppliers • Co-creation of product (or parts) with suppliers • Vertical integration: ownership of suppliers' plants or co-location with them	HCSC GSC RESC USC CDSC SDSC
Digitalization in sourcing	Real-time data sharing, monitoring and tracking for supporting integration in purchasing	HCSC GSC RESC USC CDSC SDSC

(continued)

Table 4 (continued)

Key practices	Examples of practices from cases	Supply chain strategies
Cultivating relationships with suppliers according to specific priority areas	• Strict supplier audit / compliance to regulations (e.g. sustainability) / certifications (e.g. industry-specific) • Supplier award	HCSC GSC RESC CLSC HSC CDSC SDSC
Production process		
Design of production lines	• Co-development of production technologies with providers • Full customization of production lines for product category	HCSC GSC RESC CDS
Digitalization in production processes	• (Full) automation of production lines • Automation limited to some production lines / phases • Real time data exchange between machines and informative systems to monitor the shop floor • Partially digitalized data collection from shop floor for monitoring	HCSC GSC RESC
Sustainability and efficiency in production processes	• Sustainability practices in production (wastes, renewable energies) • Lean manufacturing / just-in-time	GSC RESC CDSC
Cultivating excellence in operations according to specific priority areas	• Investments in both training and technologies for operational excellence • Integration of production and logistics operations for scale advantages • Pursuing trade-off between flexibility and full-capacity utilization	HCSC GSC RESC HSC CDSC
Supply chain configuration		
Defining relationship with distributors / logistics providers	Long-term relationships with wholesalers and / or transportation companies	GSC RESC CLSC USC CDSC

(continued)

Table 4 (continued)

Key practices	Examples of practices from cases	Supply chain strategies
Digitalization in supply chain configuration	• Automation of warehouses logistics and internal transportation • Integration (informative / digital management systems) for real-time data sharing in outbound logistics • Integration (informative / digital management systems) for real-time data sharing in both inbound and outbound logistics	HCSC GSC CLSC USC CDSC SDSC
Sustainability in supply chain configuration	Circularity, sustainability and environmental-aware practices in logistics (include reverse logistics, packaging, transportation and collaboration)	HCSC GSC RESC CDSC
Processes supporting transportation management	• Optimization of transportation (e.g. trucks loading, last mile delivery) • Intermodality for outbound logistics	HCSC GSC RESC USC CDSC
Processes supporting warehouses management	• Optimization and reduction of stocks, considering buffers • Integration of processes (warehouses management and distribution)	HCSC GSC RESC SDSC
Targeting downstream supply chain configuration according to specific priority areas	• Multi-modality in outbound logistics for last mile delivery • Centralized supply chain finance system • Continuous replenishment based on product category	GSC RESC USC CSCS SDSC
Customer relationship		
Defining kind of relationship with customers	• Long-term customer relationships • Co-creation of products / services / solutions with customers • Collaboration in design and production of technological and logistics processes and systems with customers	HCSC GSC RESC CLSC CDSC SDSC
Cultivating relationships with customers according to supply chain strategy	• Agreements on IPR management • Ensure level of service, dynamicity, flexibility, direct delivery in adapting to customer requests	HCSC GSC RESC USC HSC SDSC

(continued)

Table 4 (continued)

Key practices	Examples of practices from cases	Supply chain strategies
Digitalization in customer relationship	• Ensuring visibility on process advancements to customers • Downstream integration for information sharing/integration of processes with customers • Investments in Digital Marketing/Customer experience/journey	HCSC GSC RESC CLSC CDSC
Processes supporting demand planning and forecasting and marketing	• Data collection and analysis through different means to target marketing and better planning and forecasting • Multi-/omni-channel selling and marketing strategy	GSC RESC CDSC SDSC

strategies. The same practice can be applied with a different scope according to the supply chain strategy which is aimed to be realized. For example, the real-time data sharing, monitoring and tracking for supporting integration in purchasing (under the macro-practice of *digitalization in sourcing*) is performed by companies addressing a strategy of: Hyper-connected supply chain (e.g. *CarveSupply*, with a significant level of trust and transparency to ensure real time sharing of data on warehouses and deliveries), Global supply chain (e.g. *AutoSupply*, with tracking aimed at supporting the strategy of multiple sourcing and safety stocks), Urban supply chain (e.g. *MealsOnWheels*, which fixes very high and restricted parameters in supplier selection in order to guarantee a purchasing process of excellence, guaranteeing continuity and full capacity utilization in the urban-level downstream supply chain), Customer-driven supply chain (e.g. *FoodPrepare*, with a high level of information integration to optimize the procurement of raw materials), Service-driven supply chain (e.g. *LogisticService*, achieving the system integration with suppliers to guarantee last mile distribution and multimodal transportation).

In this sense, we can argue that results provide an overview of the practices performed by a variety of companies of European supply chains, with each practice to be considered according to the company's context and aims (especially in terms of supply chain strategy). The groups of practices presented in Table 4 can represent a reference for companies aiming to shape their supply chains (in terms of structure, strategy or single objectives or performances) according to one or a combination of more supply chain strategies.

12 Conclusions

Nowadays, macro-trends and sectoral-specific evolutions are changing the way companies produce, distribute and build relationships in their supply chain. Therefore, companies are required to properly design and manage their supply chain activities in order to reach the goals of effectiveness and efficiency, as well as to evolve towards more sustainable and resilient structures.

This chapter provided a study of multiple cases of excellence among European supply chains. A total of 18 cases have been investigated across 8 industries considered among the key ones for European economy, i.e. Automotive, Aerospace, Fashion, Chemical, IT, Distribution/logistics, Furniture, Food and Beverage. Related matching with the 10 supply chain strategies and best practices representing a reference for European supply chains are presented.

Results show that European industries are evolving in different ways according to their context-specific features, but their evolutions are mainly characterised by digitalization/adoption of enabling technologies, new business models (and value offers), and new roles and structures of the supply chain. Successful companies in each of these industries are shaping their processes along these directions, and activating one or a combination of supply chain strategies according to their main objectives. All cases are adopting practices for digitalization of all dimensions analysed in their supply chain, i.e. Products and services, Sourcing, Production process, Supply chain configuration, Customer relationship. Practices highlighted in each supply chain dimension regarding new business models (and processes to enact them) include: defining products and services portfolio and sustainability in products and services; cultivating excellence in operations according to specific priority areas, and including sustainability and efficiency in production processes;

Moreover, practices adopted by selected companies are driving new roles and structures of the supply chain, considering one or a combination of supply chain strategies. Examples of categories of practices are: outlining value chain and strategy, and processes supporting products and services development; supplier selection and evaluation; defining kind of relationship with suppliers, distributors/logistics providers, customers; cultivating relationships with suppliers and/or customers according to specific priority areas; design of production lines; specific processes for transportation and warehouses management, demand planning and forecasting and marketing; targeting downstream supply chain configuration according to specific priority areas.

As already highlighted, the same practice can be applied with a different scope according to the supply chain strategy which is aimed to be realized. In this sense, results of this multiple case study provided a wider and more practical perspective to be considered in the definition of the intervention priorities, policy actions and funding schemes aimed at sustaining European supply chains.

Due to the qualitative research design, the results from the analysis of the selected 18 cases can't be generalized to all European industries, but we can argue all of them are representative of many key practices highlighted in the selected sectors. Results summarised in Table 4 provide a reference of potential combinations of practices and enabling technologies to be considered by managers in their decision-making process to effectively and efficiently implement each supply chain strategy (or combination of two or more strategies) in their company and its supply chain.

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Policy Recommendations for Supporting Supply Chains with Horizontal Actions

Ricardo Zimmermann, Ana Cristina Barros, Pedro Pinho Senna, Elena Pessot, Irene Marchiori, and Rosanna Fornasiero

Abstract This chapter aims to identify the supply chain (SC) issues that can be considered "horizontal", as they are cross–sectorial and faced by most companies operating both in production and distribution sectors, and to propose a set of policy recommendations that can support public and private organisations to promote and foster innovation and competitiveness of future European SCs. The definition of the Key Horizontal Issues (KHI) is the basis for developing 12 policy recommendations regarding infrastructure requirements, technological and organisational improvements and regulatory developments needed to set the stage for the European SCs for the future. Specifically, the policy recommendations entail assuring appropriate standards and legislation for European SCs; educating and training professionals for the future SCs; drafting of international agreements aiming at future European SCs; supporting and fostering incentives and funding schemes; promoting reference bodies for European SCs; and establishing infrastructure for fostering of future European SCs.

Keywords Policy recommendations · Key horizontal issues · European supply chains

1 Introduction

Contemporary Europe has been experiencing unprecedented circumstances in several scopes, such as new social and consumption habits, fast development of new technologies, environmental degradation, resource depletion and climate change (Fratini

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et al. 2019; Stachova et al. 2019; Szücs 2020). As a result, there is a growing demand for transformative change in how governments, companies and society as a whole tackle these challenges.

Supply chains (SCs) are complex environments that encompass a great number of actors and processes and are highly impacted by the current changes and threats (Wieland et al 2016; Calatayud et al. 2018; Zimmermann et al. 2020). In this sense, strategies for the SCs of the future have been explored in Fornasiero et al. (2020) to assure a cross-cutting approach and identify major horizontal issues to be faced also at the level of policies definition, capacities development and necessary infrastructures improvement. A Key Horizontal Issue (KHI) consists of a combination of challenges encompassing (and common to) all SC dimensions, models and strategies, and all sectors, i.e. distribution, discrete processing and manufacturing. The horizontal nature of these issues makes them especially relevant due to the potential impact they can have in a vast number of sectors and different types of SCs. Indeed, they are the core building blocks that should be addressed in a complementary manner, in order to ensure a higher value, successful and full impact on SC innovation for all research needs.

This chapter aims to identify a set of KHIs and present policy recommendations to be suggested in order to support policy maker and public organisations, such as the European Commission, Research and Technological Centres, Industrial Associations to promote and foster innovation and competitiveness of European SCs and improve the tools and the public actions to sustain the companies in facing the future challenges. Thus, the main answer addressed in this chapter is:

RQ. What are the main actions that the responsible public/private actors should develop in order to support European SCs to be prepared for the future challenges?

Moreover, the definition of policy recommendations is based on the core guidelines of the "Horizon Europe" framework, in order to guarantee their fit to the strategic priorities of the EU research and innovation framework programme for the next years. Horizon Europe builds around the vision of "a sustainable, fair and prosperous future for people and planet based on European values" and is aligned with the 17 sustainable development goals proposed by the United Nations (European Commission 2018a).

The application of supply chain management (SCM) insights to policy debates could present notable benefits to both the public and private sectors, and vastly increase the awareness of the significance of SCM field among practitioners and legislators. SCM researchers should give more attention to policy research as this field is specially well positioned to communicate with public decision makers as both, policy making and SCM, are built on the focus on interdependencies and processes using a systems perspective (Tokar and Swink 2019). Although SCM researchers have the unique capability to make important contributions to policy research in a variety of areas, they have given little attention to public policy implications of their work. Tokar and Swink (2019) call for SCM researchers to expand the full network of actors in their research to include government and nongovernment organisations. Given the rapidly changing geopolitical and regulatory environments that influence and sometimes disrupt SCM around the world, the policy area represents a rich opportunity for study, offering the potential for contributions that can affect practice in different ways than conventional SCM research. Research should seek to understand and investigate the unique SCM and public policy characteristics, explore comparative studies across countries, and/or identify more generalizable timely solutions at the intersection of SCM and public policy (Fugate et al. 2019).

The remaining sections of this chapter are structured as follows. The methodology used is presented in Sect. 2. Section 3 describes the key horizontal issues, while Sect. 4 presents a set of policy recommendations. Finally, the main conclusions of the chapter are discussed in Sect. 5.

2 Methodology

The identification of the KHIs and the development of policy recommendations entailed an extensive data collection. Multiple sources of data were selected, including primary and secondary sources. Primary data were collected by means of the consultation of experts and the workshops organised in Brussels, Zaragoza and Porto in the first semester of 2019 involving more than 100 experts from industry, research organisations and governmental bodies. Data and opinions collected from these sources were integrated with the results from the review of roadmaps, research agendas and reports on the specific topics (i.e. KHIs and their implications at SC level), and other relevant documentation from federations, national platforms, clusters, European Commission and other reference organisations.

Expert elicitation was applied following the guidelines proposed by Morgan (2017). This approach allowed to keep the KHIs at SC level as the experts were able to easily shift from a pure research-based approach to the definition of a policy need on the specific themes they highlighted. Secondly, the integration between the issues identified by the experts participating to the consultation and the KHIs identified in the secondary sources allowed to further enhance the validity of the results.

In the first phase of data analysis, the KHIs were identified as the issues requiring cross-cutting approaches and interventions by organisations and decision makers at regional, national and European level, and that cannot be (or require a significant effort to be) directly influenced by single companies or SCs. Specifically, the analysis of the first list of horizontal issues was performed by defining codes (i.e. classes) of issues that were qualitatively different at macro level. Subsequently, the sources collected were further reviewed to identify the sub-issues, i.e. the micro-level issues, as the possible areas of intervention for each KHI (or macro-level issues) that had specific impacts on the single company or in the single SC or influenced by their actions.

The second phase of data collection and analysis was aimed at formulating a series of policy recommendations for each KHI. A preliminary important step towards the development of policy recommendations is the early identification of the target audience—which is the public to whom the document is intended to be delivered and is

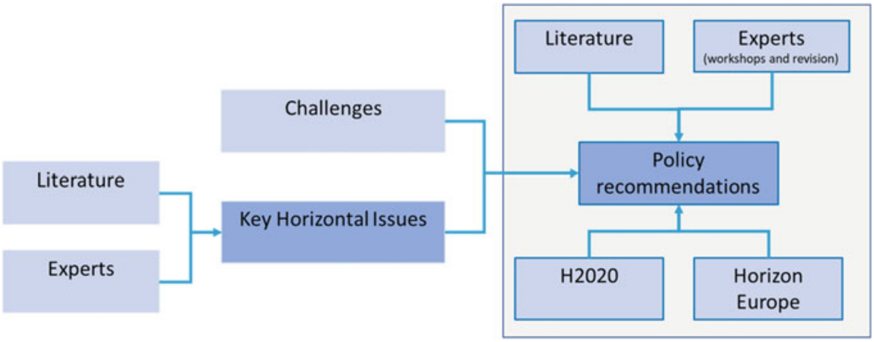

Fig. 1 Methodology for the development of the policy recommendations

expected to act upon it—in order to guarantee the use of the appropriate tone and terminology. In this work, the primary target audience is European Commission, as well as institutions that usually inform the European Commission, such as Research and Technological Centres, Public Privacy Partnerships, and Industrial Associations. Beyond the sources of data for the KHI identification, the recommendations were developed by mean of literature review and collaboration of experts. Experts were involved in two stages: (1) during the participation in a workshop, and (2) in the review of the policy recommendations. The workshop took place in Porto and participants discussed the KHIs in groups and suggested actions to be considered in the development of the policy recommendations. In order to validate the results of the literature review and of the workshop, other experts, with expertise in the identification of recommendations for public bodies, were then invited to contribute in the process of revision, aiming to enhance the reliability of the research. A total of 12 policy recommendations were identified. Figure 1 shows the methodology used to develop the policy recommendations.

The recommendations presented in this chapter may come in the form of: (1) a policy, understood as a set of ideas or plans that is used as a basis for making decisions, and represents a long-term commitment; (2) a project, which is a temporary effort with the purpose to create a specific solution; or (3) a programme, which can be defined as a set of related projects managed in a coordinated way in order to obtain broader benefits. The recommendations may also demand new mechanisms or instruments specifically for the European Commission.

The structure used for drafting the recommendations portrayed on this chapter follows the works of Morgan (2017), Doyle (2017) and Copeland (2017), as well as the structure used by OECD (2019). It comprises of a series of actions to be addressed, interlinked through a concise and well-established framework that aims at providing meaningful and summarized description of the selected recommendations.

3 Key Horizontal Issues

The horizontal issues presented below emerged from the analysis of both primary (i.e. the consultation of experts and workshops) and secondary sources (i.e. literature review).

The KHIs consist of a set of transversal topics that affect all the SC dimensions and strategies, and are related to all industrial sectors (in this work, discrete manufacturing, process industry and logistics and distribution are considered). The set of KHIs identified is: (1) Standardization; (2) Regulatory framework; (3) Training and education for skills gaps; (4) International agreements; (5) Incentives and funding schemes; (6) Reference bodies for European SCs; and (7) Infrastructure.

The first KHI refers to the lack of standards for the management of the SC processes and the difficulties for companies to implement standards, as the legislation between European countries has not been harmonized yet. Moreover, independent associations and standardization bodies do not consider dissemination activities and this represents another obstacle for the full implementation of the already existing standards and regulations. *Standardization* refers to the implementation and development of technical standards based on consensus of different parties (firms, consumers, interest groups, standards organisations and governments), concerning aspects with a direct impact on SC dimensions and performance that require the setting of common conditions and characteristics. Standards are important since they are aimed at covering “grey zones”, establishing commonalities and enhancing better interconnections between SC tiers but at the same time, it is important that standards don’t slow down innovation for all SC actors and in all SC dimensions.

As for standards, there is also a lack of harmonization at local, national and European levels of *regulatory frameworks* defined as the compendium of information and procedures on tax, customs, required regulations, relevant rules, abiding laws (or new). This KHI has arisen from the identification of a lack of legislation on specific issues with a direct impact on SC dimensions and performance. European-wide harmonization or reinforcements of legislations and normative systems of rules on SC issues are required at local, regional and European levels, as well as specific legislations at these levels. Legislations should be neutral to technology, avoid dumping strategies, and push innovation capacity of all SC actors. Different bodies should promote new regulatory frameworks also through the collaboration with SC professionals.

Training and education skills gaps refers to the necessity of identify the new skills, as well as hard and soft competences, required to the workers by the implementation of new technologies and SC strategies. There is also the need to enhance the workers’ safety and well-being in SC operations.

The KHI on *international agreements* is related to the lack of a systemic perspective on the overall SC in the existing agreements and therefore companies are still facing barriers in dealing with the terms and conditions in different areas of their operations. Moreover, it is necessary to foster participation, joint efforts (and actions) and collaboration between the European non-European countries not only for business reasons but also for research, innovation in the SC field.

Considering the initiatives already proposed in the European work programmes other *incentives and funding schemes*, which include measures and supporting instruments aimed at encouraging demonstrations (i.e. developing business cases) and pilot-tests are needed. Digital technologies have to be tested in safe environments and in real contexts and, as well as their large-scale applications; capacity building by leveraging on entities such as the Digital Innovation Hubs and promoting training vouchers should be managed at regional, national and European levels.

The KHI on *reference bodies* for European SCs entails the need for specific bodies, internationally recognized, to deal with topics like defining, deploying and measuring standards on SC, promoting standardized performance indicators models and monitoring system to collect data on European SCs' practices, strategies and instruments.

Finally, *infrastructure* refers to the lack of integrated and secured communication infrastructure with efficient and real-time data exchange, visibility, advanced and secure data management along SCs. Moreover, it encompasses the requirement for smart (green) energy infrastructure and services, and investments in logistics infrastructure to move goods all over European territory, to prioritize maintenance equipment, to promote flexible integration between freight and people transportation to avoid congestion in urban areas.

4 Policy Recommendations

This section displays the policy recommendations that derive from the KHIs and can be grouped in the following macro-areas:

- Assuring appropriate standards and legislation for European SCs;
- Educating and training professionals for the future SCs;
- Drafting of international agreements aiming at future European SCs;
- Supporting and fostering incentives and funding schemes;
- Promoting reference bodies for European SCs;
- Establishing infrastructure for fostering of future European SCs.

The KHIs standardization and regulatory framework are both addressed in first macro-area, with the related policy recommendations.

4.1 Assuring Appropriate Standards and Legislation for European SCs

Despite the continuous efforts carried out by different Governments across Europe, the lack of harmonised legislation and standards among countries is still a concern and generates logistics and administrative burdens/costs. Thus, there is a need to foster the harmonisation of legislation and standards on SC related aspects in order to simplify procedures for businesses and customers as much as possible.

Due to their collaborative and global nature (Zimmermann et al. 2019), SCs are highly impacted by differences in regulations. When it comes to the free movement of products across Europe, industry sectors can be divided into two groups (European Commission 2019a): harmonised sectors and non-harmonised sectors. Harmonised sectors are subject to common rules, which provide a clear and predictable legal framework for businesses. If manufacturers follow these rules, their products can be sold freely in the market. In the majority of sectors (e.g. electronic and electric equipment, machinery, lifts, medical devices), however, EU legislation is limited to essential health, safety, and environmental protection requirements. In other sectors, such as automotive and chemicals, legislation provides more detailed requirements obliging certain types of products to have the same technical specifications. Non-harmonised sectors are not subject to common EU regulation and the national rules are subject to a notification procedure that ensures they do not create undue barriers to trade (European Commission 2019a). Approximately half of the trade in goods within the EU is covered by harmonised regulations, while the other half is accounted for by the non-harmonised sectors (CECE 2019).

In terms of standards, the European Committee for Standardization (CEN) has established agreements with the International Organization for Standardization (ISO, Vienna Agreement) and the International Electrotechnical Commission (IEC, Frankfurt Agreement) aimed at promoting harmonization of standards on the international level. Thus, the intent is to provide benefits of the international standards to international trade and markets harmonisation, with high level of convergence between the European and international standards. This occurs through a framework for optimal use of resources and expertise available on standardization procedure, and through a mechanism of information sharing between internal and European Standardization Organizations (ESOs) with intent to increase the transparency of ongoing work at international and European levels (European Commission 2019c).

Standards are considered vital tools for enabling the adoption of technologies and innovations, especially when considering the industrial scenario. Their ever-increasing drafting and establishment by numerous standard bodies have contributed to the improvements seen in safety, security, agility and quality of operations, of componentry development, and of organisations. Nevertheless, this same aspect of the standardization effort is currently considered a disadvantage for companies, since it makes difficult for the seamless integration and interoperability required in the digital industrial and logistics environments (Lu et al. 2016).

Finally, particular attention has to be given to standards and legislations related to logistics topics for the development of a common transports policy. According to the European Environment Agency (EEA 2019a), transports account for around a third of all final energy consumption, for more than a fifth of greenhouse gas emissions and are also responsible for a large share of urban air and noise pollution. In this sense, the creation of regulatory conditions to foster greener transport alternatives is required and regulation and standards on the use of multimodal transportation is especially relevant. Multimodal transports' share among the total number goods transportation is still very low (European Commission 2018b) and more actions and programs are needed. Nowadays, differences in technical equipment, infrastructural facilities available and administrative and public structures, regulation and standards are the major obstacles to comprehensive multimodal transportation management within and beyond EU borders. Moreover, the incentive to multimodality presupposes the incentive to a balanced set of investments in infrastructure of all the transport means. In the last decades, due to incentive policies and private investments, roads as means of transport have been developing in a faster pace when compared to other modes. Short sea shipping has also been fostered in the last years by the EC, presenting a growing relevance in terms of gross weight of goods all around Europe (Eurostat 2019). However, the adoption of multimodal transports relies on a balanced set of options, including (and highlighting) rail, an efficient and sustainable option, particularly when combined with other modes. In transportation systems, the rail freight is usually cheaper than the road freight as train can carry larger volumes over longer distances. In addition, railroad transports are four times more fuel efficient than road transportation. On the other hand, rail transports are characterised by a certain lack of flexibility, as routes and times usually cannot be adjusted. Road transportation tends to be more expensive but offers flexibility in terms of final destination and volume of goods to be transported.

Table 1 presents the three policy recommendations proposed on the topic of regulation and standards.

4.2 Educating and Training Professionals for the Future SCs

According to the American Production and Inventory Control Society (APICS), the industry leader in SC certification, training and networking, and now part of the Association for Supply Chain Management (ASCM):

> Supply chain managers are crucial to the global economy. They represent a unique discipline responsible for supporting the global network of delivering products and services across the entire supply chain, from raw materials to end customers. Specifically, supply chain managers engage in the design, planning, execution, control, and supervision of supply chain activities with the objectives of creating net value, building a competitive infrastructure, leveraging worldwide logistics, synchronizing supply with demand, and measuring performance globally (APICS 2019).

SC requires a wide range of multidisciplinary skills to ensure its correct management in the industry and the company competitively. In this sense, an exhaustive identification of the competencies required for the professionals in SC is crucial. With an ever-evolving technological and economic landscape, the SC education and professional development experts need to work together to identify the competencies that every workers (managers, technicians and specialized operators) should reflect. This requires close collaboration with the industry to ensure that the mapping of

Table 1 Policy recommendations on regulation and standardization

Policy recommendation	Main issue	What should policy makers do?
Fostering harmonisation of legislation and standards on European SCs	Different legislation among EU countries in SC related aspects generates costs and harms transparency of transactions, both for companies and end consumers	• Stimulate a continuous effort toward the harmonisation of SC regulations and standards • Simplify procedures for businesses and customers • Facilitate the access to information regarding regulation and standards • Create work groups (with a broad coverage in terms of countries, industry sectors and company sizes) aimed at promoting the continuous convergence and adaptation of legislation and norms • Encourage harmonisation effort towards standardization of enabling technologies used within European SCs
Disseminating standards among EU SC stakeholders	Current and former activities developed in the context of European Research programs or by independent associations and standardization bodies do not consider dissemination activities	• Promote sensible dissemination of knowledge on the use of, contributions to, and development of standards that are commonly used in SC-related activities • The dissemination activity can occur through the Digital Innovation Hubs initiative and through the European Logistics Association, as well as other European associations • The communication of standards can be included in the new Horizon Europe program as a requirement for call proposals

(continued)

Table 1 (continued)

Policy recommendation	Main issue	What should policy makers do?
Facilitating and boosting multimodal transportation	Imbalance in the use of different transport modes (air, inland waterway, rail, road and maritime). Lack of incentives to the use of multimodality	• Development of legislation and policies which facilitate and stimulate the implementation of multimodal transportation • Foster a broad discussion on the Combined Transport Directive (Council Directive 92/106/EEC of 7 December 1992) resulting in a wide update of or the creation of a new directive • Ensure the protection of companies and consumers rights in multimodal transportation • Create mechanism to guarantee the traceability of loads in the context of multimodal transportation • Minimise the imbalance in terms of documentation and customs control in the mode change points in order to make the changes faster and smoother (especially in seaports)

competencies reflects the reality of the needs in SC training demanded by the companies. Due to the growing relevance of topics such as a broader understanding and application of sustainability issues, emergence of new technologies, digitalization and a fundamental review of processes, SCM is going through a deep transformation (Min et al. 2019). This transformation requires the continuous alignment of the competencies of the SC workforce with the new requirements, in order to provide the companies with SC professionals that meet their needs. For example, with the intensification of the personalized requirements, it becomes essential for managers to develop capabilities as creativity and critical thinking to sense shifting patterns in customer preferences and subsequent demand changes and to respond to the customers ever more demanding and sophisticated requirements at a nearly individual level. Another example comes from the adoption of new technologies such as the additive manufacturing: workers has to be able to use the new 3D printers and also managers have to develop skills as decision making to face the structural changes of the SC and be able to manage new relationships since there will be just three major participants (a focal firm, its immediate supplier, and customer) (Ben-Ner and Siemsen 2017).

Table 2 Overview of the skills and competences identified for the SCs of the future

Category	Skills/competences
Personal skills	Decision making, analytical skills, leadership, teamwork, creativity, learning ability, critical thinking, change management, conflict resolution, communication skills, cultural awareness/global citizen, holistic SC thinking, consultancy skills, management of diversified KPIs, corporate governance, costs management, evaluate offers & supplier selection, forecasting of the demand, intellectual property, quality management, risk management
Technology	Data analytics, human-machine interaction, automation (PSM technology), Enterprise Resource Planning/material requirements, procurement IT systems, e-procurement technology, remote virtual working, technology planning, openness to new technologies
Environment	Principles of circular economy, closed loop SCs, knowledge about carbon footprints, green production, green logistics, green sourcing, green packaging, green accounting exposure to quantitative techniques
SC configuration	Coexistence of lean (or efficient) and agile (or responsive) SC features, new ways of SC partnering and contracting, Exclude, global sourcing/supplier acquisition, early supplier involvement, innovative sourcing approaches, collaborative innovation processes, new business models as a consequence of new technologies, coexistence of large-scale SC structure for mass customization and small-scale home-based SCs for customization and personalization

An overview of the skills and competences required for the workforce of the SCs of the future are compiled in Table 2.

Table 3 presents the policy recommendation on education and training.

4.3 Drafting of International Agreements Aiming at Future European SCs

International agreements are formal understandings or commitments between two or more countries. According to international law, a treaty is a legally binding agreement between states and can be made in the format of conventions, protocols, pacts, accords, etc., which relates to the content of the agreement (Raustiala 2005). There are several international agreements that entail specific topics which can be considered as core for the structuring and management of SCs, e.g. trade, transport infrastructures, or environment (i.e. energy efficiency and sustainability). European companies are still facing barriers and difficulties in dealing with them in their operations, especially when they are on a global base. Moreover, these agreements still lack a holistic perspective on the overall SCs and need to be updated in order to face the major changes of European (and global) SCs in front of trends such as digitalization, servitization and urban production. A first attempt is the one carried out by Nakatomi (2012) who promoted an “International Supply Chain Agreement (ISCA)”

Table 3 Policy recommendations on education and training

Policy recommendation	Main issue	What should policy makers do?
Developing the workforce for the SCs of the future	Shortage of skilled SC professionals across European countries. Gap between companies' requirements and the competences provided by education and training institutions. Current education and training programs usually do not sufficiently consider a set of relevant topics	• Evaluating available programs and promoting the reconversion of obsolete profiles, including new competences and skills demanded by the industry • Support and train companies to be able to map competences and detect the existing gaps of their SC professionals and foresee future needs • Dissemination of the new trends and tendencies in SC to allow the companies to be ready and train their professionals in advance • Promoting the creation and/or the adoption of a European SC professionals' certification and standardization • Incentivize training through tax incentives, subsidies, and individual credits • Support the use of current and future European funding programmes in the area of skills development (Erasmus+, Blueprint)

for global SCs, but mainly focused on trade issues. A key reference are also the calls for proposals already launched by the European Commission in the Horizon 2020 framework that deal with SC-related topics, or could have a relevance for the SC dimensions and practices. In this sense, European Commission should foster the widening of the scope these calls in order to consider an overall SC perspective.

Focusing on research priorities, the efficacy and sustainability of the Strategic Research Agenda for the future European SCs requires entering bi- and multilateral agreements that are aimed at promoting the continuous research, dissemination and education on the research and innovation priorities defined at the whole SC level. These agreements should be aimed also at the establishment of research and innovation networks, collaborating to enhance advancements, innovations and dissemination of topics that bear an overall SC perspective. Such agreements would occur through cooperation and partnerships between EU and non-EU research and education institutions.

A systematic framework fostering the creation of international agreements could take as example from existing experiences (e.g. the MIT global network with branches all over the world), but as a European-based initiative. Agreements should enable the creation of networks and institutions delivering SC-targeted activities including entrepreneurship, research projects on the strategic research agenda topics and training on use of enabling technologies. They should leverage existing facilities and initiatives, e.g. network of Digital Innovation Hubs (DIH), to be extended at bi- and multi-lateral agreements also with third countries. Moreover, there is the need of SC-focused agreements to encompass several topic areas, i.e. scientific (e.g. environmental and energy-related issues), managerial (e.g. SC management), industrial (e.g. issues concerning SCs of a specific sector) and policy-related (e.g. international relations). Table 4 summarises the policy recommendations on international agreements.

Table 4 Policy recommendations on international agreements

Policy recommendation	Main issue	What should policy makers do?
Promoting bi- and multi-lateral agreements with an overall SC perspective	Due to the lack of a systemic perspective on the overall SC in the existing agreements, companies are still facing barriers in dealing with the terms and conditions in different areas of their operations	• Systematization of analyses and identification of gaps between existing agreements and necessities on SC-related topics • Create a panel of experts from industrial, scientific and legal environments, managed by the European Commission and promoted by all EU countries • Define priorities of intervention for international agreements that address SC dimensions, actors and strategies • Identify and implement initiatives to support bi- and multi-lateral collaboration between EU and non EU-countries on identified priorities • Promote the launch of calls for proposals aimed at international cooperation and bureaucratic simplification, and involving more European Commission Directorates

(continued)

Table 4 (continued)

Policy recommendation	Main issue	What should policy makers do?
Supporting the establishment of R&D networks for advancements and dissemination of SC-related topics	With the growing globalized SCs, international agreement are needed to improve collaboration with research and education institutions outside European boundaries	• Enter international agreements aimed at the establishment of research and innovation networks focused on SC-related topics • Foster cooperation and partnerships between EU and non-EU research and education institutions to leverage on commonalities and peculiarities in industry- and research-related issues • Allocate financial resources or find new opportunities for innovation or exploitation of existing facilities and initiatives • Networks should be co-created by Higher Education Institutions, Member States and the European Commission and encompass several research areas that deal with SC-related topics • Stimulate the creation of networks and institutions delivering SC-targeted activities • Monitor cooperation activities sustained by the agreements

4.4 Supporting and Fostering Incentives and Funding Schemes

Incentives and funding schemes are comprised of support actions that encourage demonstrations and pilot-tests of technologies in safe environments and real contexts, as well as their large-scale applications. Also, there is lack of common definition of SC best practices characterized by a set of KPIs, as well as their sharing and implementation among European companies and the need for better funding that combines efforts from public and private sectors is required for fostering faster and greater improvement of SC activities at European level.

The European Framework Programme for Research and Technological Development is at the ninth edition with Horizon Europe (FP9). Since its adoption in 1984, the budget allocated have significantly increased until today and have supported great results and technological breakthroughs (European Ccommission 2018a). Through this Research and Development policy, the European Commission aims to promote the collaboration of the different academic and industrial parties to foster the European strengths and to develop strategic technologies. Based on the principles of open innovation and trustful collaboration between different countries, the European Commission looks to encourage and support growth, job creation and adaptation to the digital transformation. Since the first program, the budget allocated has increased from 3.8 billion € to 77 billion € (European Commission 2018a).

However, it appears that, due to a lack of follow-up, some of the outcomes and results from strategic European projects were "lost" and not fully exploited after their conclusions. Most of the time required to ensure that a viable commercial product or service is reached comes after the project closure, through steps that are not usually defined as part of the project proposal procedure. A systematic follow-up of project outcomes that ensure the full and complete exploitation of project results after its completion is a real need. There is a need for fostering effective collaboration with established and future projects, thus ensuring projects' continuity, especially on SC-related topics.

Moreover, a lot of improvements could be achieved by defining and adopting best practices for SCM, considered one of the critical areas throughout Europe, and encompassing many technologies. For example, a common framework is missing to establish common practices and language, to be applied to the different sectors where SC is of first importance. Differences in work culture from one country to another, from one type of industry to another, could be leveraged and integrated to define different configurations of SCs. The adoption of best practices regarding common goals across Europe would lead to a faster, more reliable and more efficient achievement of competitive advantages and sustainable development goals. For instance, SCs have significant carbon footprint, which could be mitigated through establishment of common mechanisms in the different European industrial sectors, thus, greatly contributing for the European goal to fulfil the Paris Agreement and diminish the environmental impact of SCs.

Moreover, the definition of KPIs related to the SC is an important step to recognize and acknowledge best practices to be included in a common framework throughout European industrial landscape. KPIs would also enable prioritizations of some particular aspects, such as sustainability, circular economy and carbon footprint. These should be properly defined, adopted and disseminated by different stakeholders, including private partners and public organisations, which are necessary to bridge the gap in the SC practices and to further integrate research developments and industry priorities. Bearing this context, the creation of a network structure is required for fostering innovative, risk-tolerant, and flexible financing mechanism as well as inclusive market development approaches within EU. These initiatives would address the financing gap in SC transformation through innovation, i.e. affecting the on-time implementation of industrial and societal programmatic priorities of the new Horizon Europe.

A key aspect to take into account is that conducting technology-risky projects with great business potential could either lead to game changing services or processes, or to (temporary) failures. Therefore, the financial risks should be shared between public sectors (who will benefit indirectly from high potential outcomes) and industries (who will benefit directly from them). The creation of Venture Capital led by both public and private sectors would help to create synergies to deliver the next game changer innovations. Table 5 presents three policy recommendations on supporting and fostering incentives and funding schemes.

Table 5 Policy recommendations on supporting and fostering incentives and funding schemes

Policy recommendation	Main issue	What should policy makers do?
Enhancing collaboration based on European Projects results	Effective collaboration with future projects, established networks and SC industry is crucial for a project to create a follow-up of the outcomes. Current lack of visibility of the project results and lack of collaboration through different segments. Need to further support funding for large-scale projects (TRL 7 and above)	• Identify and evaluate the existing collaboration mechanisms to ensure the application and continuity of the results and knowledge generated by European projects and programs • Encourage funding of pilot-test and large-scale applications of outputs and results of previous European projects • Address as main objective of the collaboration after the project completion the visibility, communication and transfer of the project results as a benefit to new initiatives in the SC sector
Establishing a prize to support and spread best practices in the SC	There is no common definition of the best practices in the SC areas for all stakeholders involved, inhibiting the proposition of KPIs. Sharing and implementation of SC best practices in European industrial landscape is scarce and seldom. There is the need to incentivize the adoption of best practices	• Creation of a prize for the development and dissemination of best practices, involving all member of the SC • Define accurate KPIs that will be used as a reference throughout Europe • Define best practices for the European SCs, following with the KPIs aimed at enhancing SC efficiency and sustainability • Ensure the communication tools to disseminate the knowledge and to apply these best practices into other sectors and other organisations

(continued)

Table 5 (continued)

Policy recommendation	Main issue	What should policy makers do?
Creating synergies between public and private sectors in funding	SC partners are usually not involved in the definition of priorities of the OEMs, be it from the public sector (government branches and industrial associations) and the private sector (suppliers and distributors)	• Setting up a stakeholder engagement and partnership structure in order to gather European catalytic funding consortium • Focusing on the (M)SME-intensive EU regions lacking access to innovation financing instruments and prioritize the candidates from those regions • Developing transparent selection criteria of evaluation requirements, expert judges, and internal/external reporting structures on the evaluation process

4.5 Promoting Reference Bodies for European SCs

Considering the complexity and broad character of the European SCs, as well as the consequent dispersion of information about main features, trends and research advances related to SC, as well as best practices, use cases in Europe appear to be difficult to be gathered in an organic and systematic way. The analysis of the existing European bodies like observatories and associations has highlighted that these initiatives aim to promote networking and dissemination activities on some specific topics and most of them have an active role in the definition of new roadmaps while also monitoring the evolution of practices and technologies. However, these bodies focus on some specific sub-topics and sub-sectors of the European networks and they do not allow to create a comprehensive vision of the status of SCs in Europe. This is also linked to the decentralization of economic data in many different databases and missing tools to aggregate data in order to create a picture of the networks at macro-level to map where the SCs are located, how the flows are handled and which are the best practices. There is lack of KPIs to measure the most important features of SCs (e.g. operational efficiency, process reliability, responsiveness, capacity utilization, sustainability), to compare SCs of the same sector or more widely of different sectors, to measure the impact of the SC at macro-economic level and the weight of added-value of different sub-activities along the networks.

For these reasons, the development and establishment of a European SC observatory is recommended. This body should integrate different approaches becoming a reference in the study and development of a strategic vision for the future SCs for industrial stakeholders, academics and policy makers A knowledge hub is a platform which aims to facilitate the access to data, information and knowledge, as well as stimulate the exchange and the creation of a network around a certain topic. Some of the main advantages of the development of this kind of platform are: the access and understanding, the availability of data and information timely and in a simple format, the accessibility to all stakeholders, geographically dispersed and with different education and background. Table 6 presents the main characteristics of the recommendation on reference bodies.

Table 6 Policy recommendations on reference bodies

Policy recommendation	Main issue	What should policy makers do?
Creating a European SC observatory	Much of the existing information and knowledge regarding SCs in Europe are difficult to find and access. There is a lack of dissemination and a clear underutilisation of good/best practices in SCs and of the results of the research projects	• Develop and establish an open data SC observatory, which will monitor and analyse the applications of novel technologies and practices, within Europe; it will merge the characteristics of the existing observatories and European hubs with the aim to be a reference in the dissemination of knowledge about SC and increase the competitiveness of European SC • Address the focus of the European SC observatory on a systemic perspective that integrates business processes, SC networks, and SC technologies • Foster the deep analysis of the European networks in order to enable the benchmarking and the cross sectorial sharing of knowledge on last research results and best practices • Monitor the future trends that can have strong affect the network performances, and define the roadmaps and research priorities for the future SCs

4.6 Establishing Infrastructure for Fostering of Future European SCs

The traffic volume in cities increased significantly over the last decades. Between 2008 and 2035, population in the EU is expected to increase from about 500 million inhabitants to more than 521 million (Eurostat 2019). Therefore, Europe ranks among the most densely populated regions worldwide. As near to 80% of the EU-citizens live in cities and congestion in urban areas almost seems to be inevitable (Haon et al. 2015). Simultaneously, the diffusion of internet, smart phones and other technologies caused a massive growth of e-commerce. Moreover, an increasing number of retailers offers same-day delivery options. From a city logistics perspective, speedy deliveries to consumers' homes, rather than stores, multiply the number of freight movements and contribute intensely to the congestion and pollution of cities (Savelsbergh and van Woensel 2016).

To put it in numbers, urban areas freight transportation accounts for 10–15% of vehicle equivalent miles, while being responsible for 25% of related CO_2 emissions; 30–50% of other traffic related pollutants, like particulate matter or nitrogen oxide; and a significant part of the noise produced. These problems are fanned by very low load factors of delivery vehicles (e.g. 38% for vans in London). Opposing these worrisome developments, EU legislation mandates zero CO_2 emissions in cities by 2030 (Haon et al. 2015).

Transportation which does not use roads needs planning and construction of a whole new infrastructure within an existing city. Conceivable concepts like the Transit Elevated Bus-TEB in China or the Hyperloop planned for LA (underground) take time, impose enormous costs with a long investment horizon, need space and therefore might not be technically or economically feasible in many cities. As congestion and pollution in urban areas require solutions in the near term, already existing infrastructure should be used. To solve the above-mentioned issues effective adaptations, which facilitate the use of eco-friendly vehicles and innovative solutions for the delivery of the last mile, are essential. These instruments encompass the expansion of a charging infrastructure for e-vehicles of different types, the transnational harmonization of standards and regulations for low-emission zones and the transformation of open spaces into parcel centres or micro depots. The implementation of these remedies demonstrated to take less time, fewer financial resources and planning capacities than introducing a new infrastructure as an alternative to roads (e.g. a rail network) (Standing et al. 2019).

Moreover, in order to supply the last mile efficiently, logistics providers depend on relevant data. Therefore, three fundamental prerequisites should be met: first of all, a fully covered 5G-network is needed with a special focus on supply gaps in rural areas and small cities. Furthermore, useful data should be transmitted via open communication protocols and standards in order to prevent information from being kept secret. As an alternative and third requirement, local enterprises and municipalities are obliged to join and pool their data in a confidential and secure IT-infrastructure (Clausen et al. 2016). The development of a powerful 5G infrastructure is promising to result in a better linkage of different system entities and thus improved information sharing. The integrated collection and processing of real-time data from different sources allows for new mobility services and assisting functions improving route planning and flow of traffic (Lernende Systeme 2019).

While 5G brings significant benefits to already existing systems, its positive impact on sustainable urban logistics is even more tremendous when the future development of autonomous driving is considered. Self-driving vehicles are highly dependent on the low latency, reliability and velocity of the new radio technology (Hawkins and Habib 2019). As mobility-on-demand-services become more affordable with Autonomous Vehicles (AVs), many urbanites might be incentivized to use these sharing opportunities: studies show that shared services can be offered at a per-mile cost comparable to private vehicle ownership and are much cheaper than on-demand driver-operated transport (Bagloee et al. 2016). As a result, the number of cars and thereby congestion and parking requirements drop substantially (Beirigo et al. 2018). For instance, studies show that connected AVs perform two to three times better at intersections than traffic lights (Bagloee et al. 2016). Furthermore, Agatz et al. (2012) show that the “shareability”-rate of single-passenger rides in most urban centres worldwide is high yet unexplored.

To maximize the potentials of AVs, any provider of such services should opt for mixed-purpose fleets, i.e. vehicles equipped with parcel lockers to transport freight and passengers simultaneously. As far as economic reasons are concerned, studies indicate that the integration of people and cargo yields higher profits (Beirigo et al. 2018). Other than that, such AVs enhance the sustainability of urban logistics as they offer an excellent solution for affordable and convenient same-day and time-window delivery requests. At night, they can be used as mobile pickup stations, while operation is also feasible on Sundays, further rectifying traffic and congestion (Joerss et al. 2016).

In general, many functionalities are feasible with the existing wireless technologies (like Bluetooth and WLAN) and infrastructure. Thus, promoting 5G and AVs is a less capital-intensive and time-consuming strategy compared to building a new infrastructure for the new radio technology. Table 7 presents the two policy recommendations on infrastructure.

5 Conclusions

Due to the rapidly changing environments that characterise contemporary society, the competitiveness of European SCs depends on a great variety of aspects, and demands the participation of a great number of actors. This chapter aimed to present a set of KHIs and recommendations that especially target European policy makers. KHIs impact both supply and demand side in the policy making as they set the framework for adoption (demand) and deployment (supply) (Exclude) of new actions for improving competitiveness of SCs. The 12 identified policy recommendations can be summarized in these macro-areas: assuring appropriate standards and legislation for European SCs; educating and training professionals for the future SCs; drafting of international agreements aiming at future European SCs; supporting and fostering incentives and funding schemes; promoting reference bodies for European SCs; and establishing infrastructure for fostering of future European SCs.

Based on research and on continuous communication with experts, the 12 recommendations represent a balanced set of suggestions that are broad and challenging, but are, at the same time, feasible in terms of implementation, with a coordinated action where private and public bodies work in a common direction. The formulation of these recommendations has considered also the core guidelines of the Horizon Europe. The new workprogramme was built around the vision of "a sustainable, fair and prosperous future for people and planet based on European values" and is aligned with the 17 sustainable development goals proposed by the United Nations. The main objectives of the programme can be described as: (i) to strengthen the EU's scientific and technological bases and the European Research Area (ERA); (ii) to boost Europe's innovation capacity, competitiveness and jobs; (iii) to deliver on citizens' priorities and sustain the socioeconomic model and values.

Table 7 Policy recommendations on infrastructure

Policy recommendation	Main issue	What should policy makers do?
Upgrading infrastructures for low-emission SCs	Due to the volume of traffic, cities are not only congested, but polluted with hazardous emissions and noise. Logistics companies are required to come up with a solution while at the same time realizing (same-day) deliveries on the last mile	• Ensure that most vehicles, use alternative, eco-friendly drive technologies, the charging infrastructure for these fuels has to be expanded significantly, both for urban and intercity logistics • Main transport routes like the trans-European core network corridors (TEN-T) should mainly be equipped with stations for hydrogen. This fuel outperforms electricity at high speed, long distance and heavy loads • Promote the conditioned offering of conveniently located open spaces. The allocation of such areas should be made dependent on the obligation of the logistics companies to use low-emission and noise-reduced vehicles exclusively

(continued)

Table 7 (continued)

Policy recommendation	Main issue	What should policy makers do?
Promoting 5G and AVs to improve urban SCs	There is a need to improve route planning and optimize traffic flow. Real-time data exchange is critical and helps integrating logistics companies and other important entities, such as public infrastructure operators, road maintenance, construction companies and cars	• Accelerate the development, implementation and diffusion of the new radio technology within logistics networks • Enhance contribution of AVs to smart and sustainable logistics, less congestion and pollution could be vast. Potential barriers to the fast development and deployment of autonomous driving include high initial costs, AV certification, liability and perception issues, Cybersecurity, privacy as well as missing research efforts. European policy makers are recommended to make the permission of broad public usage of AVs a top priority • Foster a fast, secure and reliable 5G-infrastructure which allows for the required data-exchange and integration of different system entities, like road maintenance, mapping companies and cars

An analysis of the fit of the policy recommendations to different aspects of the framework shows that the recommendations can significantly contribute to all the three pillars:

- *Pillar 1-Excellent science*. It aims at reinforcing and extending the excellence of Union's science base by means of the European Research Council, Marie Skłodowska-Curie Actions and the investments in world-class research infrastructures.
- *Pillar 2-Global challenges and European industrial competitiveness*. It aims at boosting key technologies and solutions underpinning EU policies & Sustainable Development Goals as for example: digital industry and space, civil security for society, health, climate, energy and mobility;
- *Pillar 3-Innovative Europe*. It aims at stimulating market-creating breakthroughs and ecosystems conducive to innovation by means of European Innovation Council (EIC), European innovation ecosystems (connecting with national and regional actors), and European Institute of Innovation and Technology (EIT).

Table 8 presents a summary of the policy recommendations, including the organisations to be involved in the implementation of the actions and the expected beneficiaries.

Table 8 Summary of the policy recommendations

Policy recommendation	Type of action and Horizon Europe pillar	Organisations involved in the implementation	Beneficiaries
Fostering harmonisation of legislation and standards on European SCs	Policy Pillars 1–3	EC, National Governments, Standards Development Organisations	Research institutions, industry associations, innovation hubs, companies, customers
Disseminating standards among European SC stakeholders	Programme Pillars 2–3	EC, Standards Development Organisations	Research institutions, industry associations, innovation hubs, companies
Facilitating and boosting multimodal transportation	Project Pillars 2–3	EC, National Governments	Industry/transport associations, companies, customers
Developing the workforce for the SCs of the future	Policy Pillars 1-2-3	EC, Research & education institutions, National Governments, SC associations, companies	Education institutions, SC professionals, companies
Promoting bi- and multi-lateral agreements that consider an overall SC perspective	Policy Pillar 2	EC, National & International Governments, SC associations	Companies, SC associations
Supporting the establishment of R&D networks for advancements and dissemination of SC-related topics	Policy Pillars 1–3	EC, Research institutions, National & International Governments, SC associations	Research & education institutions, companies, SC associations
Enhancing collaboration based on European Projects results: creation of a platform for data repository	Project Pillar 1	EC-DGs, Research institutions.	EC, research institutions, companies
Establishing a Prize to support and spread best practices in the SC	Programme Pillars 2–3	EC-DGs, Research institutions, SC associations, companies.	Companies, SC associations, SC professionals, research institutions

(continued)

Table 8 (continued)

Policy recommendation	Type of action and Horizon Europe pillar	Organisations involved in the implementation	Beneficiaries
Creating synergies between public and private sectors in funding	Project Pillar 2	EC, National Governments, Companies	SC associations, companies, national governments, research institutions, innovation hubs/clusters
Creating a European SC knowledge hub for sustainable, resilient and inclusive SCs	Project Pillars 1-2-3	EC-DGs, National Governments, Research Institutions, innovation hubs	EC, national governments, research & education institutions, SC associations, companies, SC professionals, innovation hubs/clusters
Upgrading infrastructures for low-emission supply chains	Programme Pillars 2–3	EC, National Governments, Research institutions, Companies	National governments, companies, customers
Promoting 5G and autonomous vehicles (AVs) to improve urban supply chains	Programme Pillars 1-2-3	EC, National Governments, Research Institutions, Companies	National governments, companies, SC associations, customers

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