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# Alternative Development Paths for Supply Chains in 2030

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*Many different megatrends such as digitalization, are posing specific challenges and opportunities for supply chains creating the urgent need to adapt and rethink the way they are organized. This paper aims to define development paths (DPs), which constitute projections into the future. The DPs are based on the analysis of megatrends, which might have an impact on the design of supply chains until the year 2030. The results are 51 possible DPs, which are derived from the identified megatrends and clustered under 22 descriptors, which are in turn assigned to the PESTLE (Political, Economic, Social, Technological, Legal, and Environmental) dimensions. These DPs consider the underlying criteria reasonability and conceivability. They describe how the future might look like in 2030 and can be used to address developments, challenges and opportunities that may arise in supply chains. Thus, this paper creates the starting basis for further research that deals with the creation of holistic industrial scenarios affecting future supply chains.*

**Keywords:** Supply Chain; Megatrends; Development Paths; Scenarios

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# 1 Introduction

The biggest trader and exporter is the political and economic European Union (EU) of 28 member states. It is expected that in the next 10-15 years 90% of the global economic growth will come from outside the EU (ALICE, 2014). Therefore, on one hand, the EU companies have to be able to adapt and gain a competitive advantage by accessing these new markets. On the other hand, companies must configure accordingly their supply chains to respond efficiently to incoming challenges, such as customization and scarcity of resources. Digitalization accompanied by acceleration of technological developments affect different industries, such as process, discrete manufacturing and logistics industry that are significant sectors for the EU's economy.

The process industries are industries where the production processes are either continuous, or the batches of materials are indistinguishable (Institute of Industrial and Systems Engineers, 2018). The product is created by using a formula to refine the raw materials leaving no way to break down the final product into its basic components (Cole and O'Donnell, 2017).

Different divisions of the process industry sector such as chemicals, minerals nonferrous metals, are united under SPIRE - Sustainable Process Industry through Resource and Energy Efficiency (Tello and Weerdmeester, 2012). These divisions comprise more than 450,000 companies, employ 6.8 million people and have a yearly sales volume of more than EUR 1.6 billion. The common feature between these types of companies is the high dependence on resources (e.g. energy). The process industry is important for Europe since it covers 20% of the overall European industry in terms of employment and sales volume (Tello and Weerdmeester, 2012).

The discrete manufacturing sector has 29.7 million employees in over 2 million companies generating a turnover of EUR6.98 billion and a value added nearly to EUR 1.63 billion; the sector represents 17% of the EU GDP (EFFRA, 2013). Companies in this sector produce distinct items that can be easily counted and the products are measurable in distinct units.

The top five branches for value added and employment in the discrete manufacturing sector are machinery and equipment, food products, metal products, motor vehicles and electric equipment (EFFRA, 2013).

As reported by Eurostat and the alliance for European Logistics, the logistics sector constitutes the single biggest industry in Europe: it creates 7 million employees

and the revenue per year is more than EUR 900 billion, representing around 7% of total European GDP (Savills Investment Management, 2016).

In order to address these challenges and benefit from the opportunities provided by megatrends, companies use mechanisms such as collaboration and reconfiguration of supply chains. Berger (2015) identified the top ten trends impacting the supply chain: (i) rising customer requirements regarding reliability, (ii) rising customer requirements regarding flexibility, (iii) increasing demand volatility, (iv) rising customer requirements regarding lead times, (v) rising customer requirements regarding cost, (vi) increasing uncertainty, (vii) increasing complexity, (viii) increasing globalization, (ix) increasing heterogeneous customer requirements, and (x) increasing speed of change. Cost and reliability are revealed as the most important targets in supply chains (Berger, 2015). In the future, lead time and flexibility will also have a high importance. More recently, Kersten et al. (2017) analyzed the trends and opportunities in supply chain management that lead to digital transformation opportunities from a twofold perspective: endogenous and exogenous. Endogenous trends include: digitalization of business processes, business analytics, transparency in the supply chain, automation, networking/ collaboration, and decentralization. Exogenous trends comprise: cost pressure, demand fluctuations, government regulations/ compliance, individualization, staff shortages, risks/ interruptions, complexity, sustainability, and changed consumer behavior.

The analysis of challenges and opportunities in the supply chain has generally been addressed in the literature by focusing on one or several dimensions. For example, Zhong, et al. (2016) focus on Big Data technology and identify current challenges, opportunities and future perspectives from six aspects: data collection, data transmission, data storage, processing, decision-making, and applications. Similarly, Bechtsis, et al. (2017) study the impact of Automated Guided Vehicles for a sustainable supply chain. Barbosa-Póvoa, da Silva and Carvalho (2018) include three dimensions (economic, environmental and social) in their analysis to identify opportunities and challenges from an operational perspective. However, few studies have considered other dimensions (e.g. legal, political).

Challenges increment the complexity of supply chains in three main aspects: operational, logical and administrative (Yami, 2018). According to Yami (2018), a study carried out in 2006 performed a ranking of complexity drivers in the supply chain leading to the following result: product/ services, customers, direct materials, ship-to locations, manufacturing locations, suppliers, and distribution

centers. The actions focused on the control of the complexity of the supply chain that will have a positive impact in the competitiveness of the firm.

In this regard, handling change is an integral part of managing supply chains. However, the speed of change is so fast that it is difficult to identify where to focus the company's management resources. Under this uncertain environment a framework for the identification of future scenarios in the supply chain has been developed. The framework comprises a PESTLE analysis to identify megatrends that interact to create the challenges and opportunities future supply chains might face. This paper uses the process, discrete manufacturing and logistics industries as input in order to be able to analyze megatrends from different points of view. The results of this paper are final DPs that consider these three industries like a single system. This approach provides the opportunity to create generic DPs, which are required to build industrial scenarios.

This paper is divided into five sections. Section 2 includes a literature review related to scenario development in the field of supply chain management (SCM). Section 3 describes the methodology developed for the definition of DPs. The defined DPs are summarized in Section 4 and elaborated in detail for the technological dimension in Section 5. Section 6 entails the conclusion and an outlook on further research.

## 2 Literature Review

Today, supply chains face several challenges and opportunities, such as globalization and emerging technologies that change and shape the future of industries. Thus, it is crucial for companies to develop robust strategies and prepare for the future (Singh, 2004; Melnyk, et al., 2009). To this end, scenario planning is the most appropriate approach for a long-term planning to support decision making in uncertain situations (Schoemaker, 1993).

Scenario planning has been utilized by several studies in the field of SCM (e.g. Mazzarino, 2012; PwC, 2009; von der Gracht and Darkow, 2010). As for the planning horizon, most of the papers in the field of SCM focus on a range of 8–10 years (e.g. von der Gracht and Darkow, 2013) and a few take into account a planning horizon of more than 10 years (Jiang, Kleer and Piller, 2017). Regarding the context of the scenarios, the focus of those papers is mainly on the logistics industry (e.g. DHL, 2012; von der Gracht and Darkow, 2016). There are a few papers

that develop scenarios for the discrete manufacturing industry (e.g. Arora and Putcha, 2013; Jiang, Kleer and Piller, 2017) and process industry (e.g. Willigens and von der Gracht, 2013). To the best of our knowledge, there is not any study on industry scenarios that support decision-making in all of these three industries so that companies could take a holistic perspective into consideration. This requires a more thorough approach to manage long-term planning in the process, discrete manufacturing and logistics industry. Our research closes this research gap by developing alternative DPs that consider all the three aforementioned industries.

Scenario publications mainly use the Delphi technique to develop and present only the final scenarios (e.g. von der Gracht and Darkow, 2010; Jiang, Kleer and Piller, 2017). In the contrary, our study follows the Gausemeier and Plass (2014) approach, which is described in the methodology section. This paper also presents potential future DPs that enable companies to recognize different developments based on megatrends. From the DPs final scenarios, which reflect the overall system relations between the chosen dimensions, can be developed in further research.

The central idea of developing alternative paths for long-term planning is to lead decision makers to specific directions within the PESTLE dimensions and provide support in uncertain times (Powell, 1992). However, most of the studies give emphasis mainly on the environmental dimension (e.g. Arora and Putcha, 2013; von der Gracht and Darkow, 2013; von der Gracht and Darkow, 2016; PwC, 2009). Only a few studies (e.g. DHL, 2012; Mazzarino, 2012) have addressed all of them. Our focus lies within all of the PESTLE dimensions. Based on the gaps discussed above, this study tries to answer the following research questions:

1. What development paths might emerge from megatrends in the industrial sector by 2030?
2. How will the technological dimension particularly shape the DPs for the industrial sector by 2030?

# 3 Methodology

This paper follows the scenario technique developed by Gausemeier (Gausemeier, et al, 1998; Gausemeier and Plass, 2014) in order to create projections, which constitute developments into the future, specifically until the year 2030.

The Gausemeier approach has five stages: (i) preparation, (ii) scenario field analysis, (iii) scenario prognosis, (iv) scenario development, (v) scenario transfer. This paper presents the third stage, in which a range of possible futures (typically 2-4) is defined for each descriptor (i.e. megatrends such as globalization). These projections represent alternative and dissimilar developments of the descriptor.

Thus, this study shows all the potential future developments, which enable companies to evaluate different paths for different megatrends, instead of presenting the final scenarios that result from different combinations of a variety of DPs within the underlying dimensions. This basis allows building final consistent scenarios in further research.

These DPs are derived from the analysis of identified megatrends in previous research (Kalaitzi, et al., 2018), which in turn have been organized according to the PESTLE dimensions. Some megatrends have been rephrased if necessary in order to derive the descriptors. The decision to rephrase a certain megatrend is subject to its tendency. If the megatrend has a positive or negative inclination, it is rephrased to represent a neutral position; e.g. the megatrend "protectionism" has been renamed to the descriptor "trade policy". A descriptor can have a positive, negative and neutral DP. However, deviating settings are also feasible. Consequently, the number of DPs per descriptor is not fixed and varies by descriptor. Each descriptor is characterized by diverging DPs that express possible future states of the descriptor and describe circumstances companies and societies might face.

The analysis of the megatrends considered statistics, forecasts and descriptions of the respective megatrends found in literature (Kalaitzi, et al., 2018). Hence, quantitative and qualitative data is combined in order to derive the DPs. Additionally, several iterative workshops with three to 17 experts from different departments, sectors and with different backgrounds were conducted in order evaluate the DPs derived from literature as well as elaborate on further possible DPs. This approach provides a comprehensive picture throughout all PESTLE dimensions as well as the three industries under consideration.

Each DP is assigned to one of the PESTLE dimensions. Nevertheless, certain DPs also can have impacts on other dimensions since it is rarely that developments affect only one of the PESTLE dimensions. This is due to the comprehensive nature of the study and a holistic analysis of opportunities and challenges of megatrends.

The main criteria for the creation of DPs are its reasonability and conceivability (Gausemeier and Plass, 2014). Hence, we propose that every DP needs to fulfil certain quality criteria, namely: (i) plausibility - a DP needs to be plausible to the complete scenario team, (ii) dissimilarity - all DPs have to be distinct to each other, (iii) completeness - a set of projections within a descriptor has to provide a comprehensive set of possible developments, (iv) relevance - each DP requires a check regarding its future relevance, and (v) information content - each DP needs to add further value to the set of DPs within a descriptor. A DP can be futuristic but needs to rely on valid arguments or requires justification by statistical developments.

Suitable DPs must be distinct, so that the consistency check, needed in subsequent research for the scenario building, does not lead to many different evaluations and, hence, to inconsistent scenarios. Rather reasonable combinations of DPs are necessary for the creation of consistent scenarios.

Section 4 presents the results of this research by listing the descriptors with a definition and the assigned DPs organized by the six PESTLE dimensions.

# 4 Overview of the Development Paths

Table 1 contains the descriptors per PESTLE dimension along with a definition for each descriptor, and provides an overview of the identified DPs per descriptor.

Table 1: Summary of development paths in the PESTLE dimensions

| Dimension | Descriptor | Definition | Development Path |
|---|---|---|---|
| Political | Political Setting | Political setting describes the political activity in a society, the satisfaction level of the population and general risks that might affect a country (Campos and Gassebner, 2009). | Constant development in Europe<br>Government collapse in Europe |
| | Trade Policies | ”Trade policies are policies aimed at influencing the international commercial relations and the flow of goods and services across borders” (Jarman, 2017) affecting the availability, and therefore price and use goods and services. | Political concord in Europe<br>Protectionism<br>Free trade |
| | Confederation | ”That form of association between states in which the general government is dependent upon the regional governments has often been described as a confederation” (Bennett, 1964). | Contented union<br>Unstable confederations<br>Fragmentation |

| | | | |
|---|---|---|---|
| Economic | Global Trade Shift | Global Trade Shift describes the changes in location of economic activities between industrialized countries and emerging economies (Dicken, 2015; UNCTAD, 2012). | The pendulum shifts<br>Steady titans US & Europe |
| | Global Corporate Structures | Global Corporate Structures "define and clarify responsibilities for operational, control, and reporting processes" (Baret, et al., 2013, p.2) on a global governance level. | Think global, act local<br>Rise of born-global firms |
| | Digital Economy | Digital Economy describes the changing environment in which digitalization is becoming more and more integrated into the business environment enabling new business concepts (Brynjolfsson and Kahin, 2000). | Traditional economy persists<br>Digital potential<br>Digital impediment |
| | Financial Innovations | Financial innovation is "something new that reduces costs, reduces risks, or provides an improved product/service/instrument that better satisfies participants' demands" (Frame and White, 2002, p.3) within a financial system. | Bank and Fintech collaboration<br>A world without banks<br>Big five are the banks of the future |

| | | | |
|---|---|---|---|
| Social | Demographic Change | Demographic change describes the changes and tendencies of the population regarding age, gender, birth and death rate and migration. It also comprises longer and healthier life expectancy (Cambridge Dictionary, 2017). | Ageing population and acceleration of disparities<br>Awareness of inequalities and wealth redistribution |
| | Urban Living | ”The process of the economic development which leads to a significant concentration of human resources, economic activities, and resource consumption in cities (modern environment or refurbished buildings, studios and lofts” (Madlener and Sunak, 2011). | Smart regions<br>Smart cities |
| | Consumption Patterns | Consumption patterns describe the buying behavior and the handling of the purchased goods or services (Fletcher and Emmanuel-Stephen, 2016). | Much and cheap<br>Consumption awareness<br>DIY society<br>Individualized consumption |

| | | |
|---|---|---|
| Customer Orientation | ”Customer orientation refers to the importance an employee places on meeting customers’ needs and expectations” (Nguyen, et al., 2014, p.1097). | Individualism – focus on variety<br>Collectivism – focus on the crowd |
| Knowledge-based economy | Knowledge-based economy describes ”trends in advanced economies towards greater dependence on knowledge, information and high skill levels, and the increasing need for ready access to all of these by the business and public sectors” (Organisation for Economic Cooperation and Development, 2007, pp.434). | Investments equalize the labor market<br>Rapid changes cause unemployment |
| Digital Transformation | Digital transformation describes the changes related to the application of technologies and their integration into all aspects of human life and society, e.g. to improve performance of enterprises or convenience of social life or to change the way business is done (Probst, et al., 2017, p.10). | Rapid advancement of digitization and digitalization<br>Obstacles restraining digital transformation<br>Digital stagnation |

| | | | |
|---|---|---|---|
| | Autonomous Systems | Autonomous systems describe objects or devices that can act and make situation-dependent decisions independently without interference by humans or other outside forces and have the ability for self-governance in the performance of control functions (European Group on Ethics in Science and New Technologies, 2018; Antsaklis, et al., 1991, p.5). | Dynamic development of autonomous technologies<br>Innate reluctance to accept autonomous technologies |
| Technological | Alternative energy generation, storage and usage | Alternative energy generation, storage and usage illustrates how energy can be obtained and stored in sustainable ways. Moreover, it describes the usage of alternative energy for industrial, transportation and mobility purposes (Kleiner, et al., 2017; Hydrogen Council, 2017, p.10). | Established electrification technologies and green systems<br>Ongoing electrification and alternative energy endeavors |
| | Decentralized connection of information and physical devices | Decentralized connection of information and physical devices describes how companies cope with the masses of data and take advantage of the smart decentralized linkage (Dickson, 2016). | Dominance of global players<br>Start-ups and SMEs take up business |

| | | | |
|---|---|---|---|
| | Disruptive Production Technologies | Disruptive technologies describe developments that bring revolutionary changes to social life and to the way companies understand and do business. In the context of production technologies, the concept of Industry 4.0 reflects this emerging pattern, encompassing the integration of different technologies into an autonomous production system that can regulate itself based on knowledge and sensors (Lasi, et al., 2014; Hofmann and Rüsch, 2017). | Continuous exploitation of disruptive technologies<br>Coexistence of conventional and disruptive technologies |
| Legal | Consumer Protection Laws | Consumer protection law is defined as ”all legal principles and rules governing relationships and problems between various parties or each other in relation to goods and / or services in the aspects of life” (Azis, 2018, p.56). | Promotion of laws and full product transparency<br>Legislation is lagging behind dynamic market development |
| | Intellectual Property Laws | Intellectual property (IP) laws deal with the laws that apply for ”creations of the mind: inventions; literary and artistic works; and symbols, names and images used in commerce” (World Intellectual Property Organization, 2018, p.2). | Full security for inventors and data providers<br>Low confidentiality for data and market participants |

| | | | |
|---|---|---|---|
| | Social and Environmental Regulations | Social and Environmental regulations describe regulations that urge companies and societies to act and use environmental functions in an environmentally friendly and ethical way (Organisation for Economic Cooperation and Development, 2007, pp.253, 725; Shift2Rail, 2017). | Comprehensive regulatory framework<br>Heterogeneous regulations |
| Environmental | Climate Change | It is a "a change in global or regional climate patterns, started from the mid to late 20th century onwards and attributed to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels" (Oxford's dictionary, 2017). | Our planet is recovering<br>Our planet on the brink |
| | Environmental Resource Management | It describes the management of human interaction with the environment and aims to assure that the state of an environmental resource affected by humans is maintained for future generations, and for ecosystem integrity through considering ethical, economic, and scientific (ecological) variables (Pahl-Wostl, 2007). | Countering resource depletion<br>Rise in depletion of natural resources |

Due to numerous DPs in each of the six PESTLE dimension, it is not feasible to illustrate all DPs in detail in this paper. Hence, the focus in Section 5 is on the technological dimension. More specifically, ”Autonomous Systems” are chosen as example since these technologies are expected to progress on a high pace with vast impacts on all industries and the related supply chains.

# 5 Development Paths for Autonomous Systems in the Technological Dimension

The two DPs under the descriptor ”Autonomous Systems” are exemplarily outlined for the technological dimension.

Autonomous systems describe objects or devices that can act and make situation-dependent decisions independently without interference by humans or other outside forces (European Group on Ethics in Science and New Technologies, 2018). These technologies have an immense impact on ways of working, particularly how people will collaborate with other people, machines and virtual formats in entirely new ways (Wisskirchen, et al., 2017).

Based on the previous research (Kalaitzi, et al., 2018), autonomous systems encompass the trends robots, drones, automated vehicles/ automated guided vehicles and cyber-physical systems. The DPs take up on these trends and are described in the following Subsections 5.1 and 5.2.

This section focuses on the DPs. DPs describe how the future in 2030 might look like. Since this study is part of a comprehensive scenario generation approach, it is subject to further research to analyze which DPs are feasible in the context of a holistic scenario. The scenarios are composed of combinations of several DPs from various descriptors and different PESTLE dimensions. Hence, at this stage of research it is yet not possible to derive which implications arise, how companies need to prepare for the future, how supply chains will change concerning their configuration or how the developments will affect specific industries (e.g. process, discrete manufacturing or logistics).

## 5.1 Dynamic Development of Autonomous Technologies

This DP describes that companies are taking advantage of digital technologies to find new markets, business models and revenue streams and that human workforce can benefit from this development.

Technology advancements, especially with regard to robots, drones and autonomous vehicles are progressing at a rapid pace. Cyber-physical systems play a key role for autonomous systems in the industrial environment. They constitute enablers for efficient communication and control by transferring and exchanging data over the internet in real time. An increased exploitation of these technologies leads to a highly automated and autonomous environment which permits to improve the productivity rate (for example robots can perform 24/7) reducing quality problems, errors and down times (Wisskirchen, et al., 2017). Coupled with the ability to share and act upon the associated data and derived insights, new service and production related business opportunities arise for global players as well as start-ups. New business models emerge both within and across organizations, removing traditional silos as well as simplifying trust and contractual agreements. Automation (both physical and virtual) replaces an increasing range of human tasks (Bingley, et al., 2016).

### Implications on supply chains

The described technological advancements allow the administration of supply chains to be simplified and to operate with less cost and better customer satisfaction. In particular, the first step in the advancement of autonomous systems is at the process level in order to automate non-value added activities. In this regard, rapid changes could lead to high rates of unemployment. In this case, companies need to define approaches for reallocation of staff along the supply chain and consider the possibility to improve their capabilities since these technologies require advanced IT skills. By tracking the whole supply chain, transparency between the supply chain actors can be increased, which improves the capability to react efficiently and quick to external influences. If new business models are implemented to handle the increasing complexity of autonomous systems, the supply chain can achieve high performance in terms of agility, reliability and transparency.

## 5.2 Innate Reluctance to Accept Autonomous Technologies

This DP states that the use of advanced technologies is reshaping the work landscape intensifying competition on the labor market and causing worker displacements.

The technological development enables a high degree of automation and autonomiztion. Suppliers provide modular and standardized components so that technology solutions become affordable, but still often lack profitability (Gausemeier and Plass, 2014). Since an autonomous technology requires suites of expensive sensors, the average cost of this technology is high and this could slow down the application of this technology. A particular technological roadmap to reduce those costs is yet to be established (Omohundro, 2014; Anderson, 2016). Although autonomous technologies often lack profitability (Gausemeier and Plass, 2014) or regulations prevent the full exploitation of their potentials, automated and partly autonomous factories are progressively becoming the standard in Europe. The result is a shift from assistance of human activities to a more machine-centered environment. This development radically reshapes the work landscape and creates new business models (Bingley et al., 2016). Users struggle with operating the highly complex machines (Gausemeier and Plass, 2014). Hence, employees fear for their jobs, get frustrated and demotivated and eventually adopt a negative attitude towards emerging advanced technologies.

### Implications on supply chains

High costs, privacy and cyber security issues, low IT penetration into processes as well as a lag of technology standards make the adoption of new technologies slower and restrain digital transformation. Supply chains need to revise processes and move from traditional supply chains towards a connected, smart, and highly efficient supply chain ecosystem in order to achieve comprehensive agility and transparency.

# 6 Conclusion and Outlook

This paper identifies 51 DPs that might emerge from megatrends in the industrial sector by 2030. DPs constitute projections of each megatrend into the future.

They are grouped under 22 so-called descriptors and assigned to the PESTLE dimensions. Each DP creates different conditions that will have an impact on supply chains and their configuration.

In order to address our first research question, we have extended previous scientific publications and grey literature by taking a holistic approach and considering three different industries (i.e. process, discrete manufacturing, and logistics) as well as six PESTLE dimensions. We assessed megatrends and their associated challenges and opportunities in order to define DPs for the future. The systematic collection of information regarding megatrends and their analysis permits a complete and well-structured illustration of a set of DPs.

To answer our second research question, we exemplarily elaborated on two DPs for autonomous system by providing a comprehensive description of the two divergent DPs. Furthermore, possible implications of these DPs on supply chains and companies are described.

The construction of DPs is part of a comprehensive scenario technique. Future research will show the impacts of each DP on each specific industry and the related supply chains. Then, by using the Gausemeier and Plass (2014) methodology, it will be necessary to create the most plausible and diversified industrial scenarios. These scenarios help to define the best strategies to engage the different challenges of the future.

Our research is limited in the way that process, discrete manufacturing and logistics industries are considered as an input only. The resulting DPs are not classified by industries. Thus, this study follows a holistic approach and can be used to create scenarios for different industries in future research and to derive specific DPs for the aforementioned industries. Additionally, the DPs were validated with a small group of experts. More experts could provide other insights. Some DPs are concentrated in a European context since the focus was on existing European roadmaps. Practically, this study enables supply chain professionals to understand possible DPs and serves as basis to develop future scenarios in subsequent work.

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## References

ALICE (2014). *ALICE Recommendations to H2020 Work Programs 2016-2017*.
Anderson, J. e. a. (2016). *Autonomous Vehicle Technology: A Guide for Policymakers*. Ed. by RAND Corporation.
Antsaklis, P. J., K. M. Passino, and S. J. Wang (1991). "An introduction to autonomous control systems". In: *IEEE Control Systems* 11.4, pp. 5–13.
Arora, V. and S. Putcha (2013). "Future Scenarios for Green Chemical Supply Chains". PhD thesis. Massachusetts Institute of Technology: Massachusetts Institute of Technology.
Azis, D. E. P. (2018). "Juridical Review The Implementation of Oral Agreement is associated with the Law of Treaties and Law Number 8 Year 1999 concerning Consumer Protection". In: *Substantive Justice International Journal of Law*. Vol. 1, pp. 56–64.
Barbosa-Póvoa, A. P., C. da Silva, and A. Carvalho (2018). "Opportunities and challenges in sustainable supply chain: An operations research perspective". In: *European Journal of Operational Research* 268.2, pp. 399–431.
Baret, S., N. Sandford, E. Hid, J. Vazirani, and S. Hatfeld (2013). *Developing an effective governance operating model: A guide for financial services boards and management teams*. Ed. by Deloitte Development LLC.
Bechtsis, D., N. Tsolakis, D. Vlachos, and E. Iakovou (2017). "Sustainable supply chain management in the digitalisation era: The impact of Automated Guided Vehicles". In: *Journal of Cleaner Production* 142, pp. 3970–3984.
Bennett, W. H. (1964). *American Theories of Federalism*. Tuscaloosa: University of Alabama Press.
Berger, R. (2015). *The Supply Chain Excellence Study 2015*.
Bingley, M., J. F. Esteban Lauzán, J. Hall, G. Jagdale, M. Pfeil, M. Smith, F. Pinheiro, and H. Tardieu (2016). *Journey 2020: Digital Shockwaves in Business*. Ed. by Atos SE.
Brynjolfsson, E. and B. Kahin (2000). *Understanding the Digital Economy: Data, Tools, and Research*.
Cambridge Dictionary (2017). *Demographics*.
Campos, N. F. and M. Gassebner (2009). "International terrorism, political instability and the escalation effect". In: *IZA discussion papers* 4061.
Cole, B. and J. O'Donnell (2017). *Discrete vs. process manufacturing*.
DHL (2012). "Delivering tomorrow Logistics 2050 A Scenario Study". In:
Dicken, P. (2015). *Global shift: Mapping the changing contours of the world economy*. 7. ed. Los Angeles, Calif.: Sage Publ.
Dickson, B. (2016). *Decentralizing IoT networks through blockchain*.
EFFRA (2013). *Factories of the future: Multi-annual roadmap for the contractual PPP under Horizon 2020*. Luxembourg: Publications Office of the European Union.
*European Battery, Hybrid and Fuel Cell Electric Vehicle Congress* (2017). Geneva, Switzerland.
European Group on Ethics in Science and New Technologies (2018). *Artificial Intelligence, Robotics and 'Autonomous' Systems*. Ed. by European Commission. Luxembourg.

European Union (2015). *EU transport in figures: Statistical Pocketbook 2015*. EU transport in figures. Luxembourg: Office for Official Publications of the European Communities.

Fletcher, K.-A. P. and C. M. Emmanuel-Stephen (2016). "Social Media Engagement: Reshaping the Consumption Pattern of Generation Y Caribbean and Latin American Consumers". In: *Consumerism and Buying Behavior in Developing Nations*. Ed. by IGI Global, pp. 218–238.

Frame, W. S. and L. J. White (2002). *Empirical Studies of Financial Innovation: Lots of Talk, Little Action?* Ed. by Federal Reserve Bank of Atlanta. Atlanta, GA, USA.

Gausemeier, J., A. Fink, and O. Schlake (1998). "Scenario Management". In: *Technological Forecasting and Social Change* 59.2, pp. 111–130.

Gausemeier and Plass (2014). *Zukunftsorientierte Unternehmensgestaltung - Strategien, Geschäftsprozesse und IT-Systeme für die Produktion von morgen*. 2nd ed. München: Carl Hanser Fachbuchverlag.

Hydrogen Council (2017). "Hydrogen scaling up: A sustainable pathway for the global energy transition". In:

IGI Global, ed. (2016). *Consumerism and Buying Behavior in Developing Nations*.

Institute of Industrial and Systems Engineers (2018). *Process Industries Division*.

Jarman, H. (2017). "Trade policy governance: What health policymakers and advocates need to know". In: *Health policy (Amsterdam, Netherlands)* 121.11, pp. 1105–1112.

Jiang, R., R. Kleer, and F. T. Piller (2017). "Predicting the future of additive manufacturing: A Delphi study on economic and societal implications of 3D printing for 2030". In: *Technological Forecasting & Social Change* 117, pp. 84–97.

Kalaitzi, D., A. Matopoulos, R. Fornasiero, A. Zangiacomi, I. Marchiori, A. C. Barros, K. Pires, P. Campos, V. Amorim, V. Muerza, S. Sardesai, D. Daus, M. Witthaut, L. Aerts, and S. Balech (2018). *D2.1: Report on trends and key factors*.

Kersten, W., M. Seiter, B. von See, N. Hackius, and T. Maurer (2017). *Trends And Strategies In Logistics And Supply Chain Management: Digital Transformation Opportunities*. Ed. by BVL International - The Supply Chain Network.

Kleiner, F., M. Beermann, B. Çatay, E. Beers, H. Davies, and O. T. Lim (2017). "Current status of the electrification of transport logistic vehicles - Early niche markets and commercialization opportunities". In: *European Battery, Hybrid and Fuel Cell Electric Vehicle Congress*. Geneva, Switzerland.

Lehmacher, W., F. Betti, P. Beecher, C. Grotemeier, and M. Lorenzen (2017). *Impact of the Fourth Industrial Revolution on Supply Chains*. Ed. by World Economic Forum. Cologny/Geneva, Switzerland.

Madlener, R. and Y. Sunak (2011). "Impacts of urbanization on urban structures and energy demand: What can we learn for urban energy planning and urbanization management?" In: *Sustainable Cities and Society* 1.1, pp. 45–53.

Mazzarino, M. (2012). "Strategic scenarios of global logistics: what lies ahead for Europe?" In: *European Transport Research Review* 4.1, pp. 1–18.

Melnyk, S. A., R. R. Lummus, R. J. Vokurka, L. J. Burns, and J. Sandor (2009). "Mapping the future of supply chain management: a Delphi study". In: *International Journal of Production Research* 47.16, pp. 4629–4653.

Nguyen, H., M. Groth, G. Walsh, and T. Hennig-Thurau (2014). "The Impact of Service Scripts on Customer Citizenship Behavior and the Moderating Role of Employee Customer Orientation". In: *Psychology & Marketing* 31.12, pp. 1096–1109.

Omohundro, S. (2014). “Autonomous Technology and the Greater Human Good”. In: *Journal of Experimental & Theoretical Artificial Intelligence* 26.3, pp. 303–315.
Organisation for Economic Co-operation and Development (2007). *Glossary of Statistical Terms*.
Oxford’s dictionary (2017). *climate change*.
Pahl-Wostl, C. (2007). “The implications of complexity for integrated resources management”. In: *Environmental Modelling & Software* 22.5, pp. 561–569.
Powell, T. C. (1992). “Strategic Planning as Competitive Advantage”. In: *Strategic Management Journal* 13.7, pp. 551–558.
Probst, L., B. Pedersen, O.-K. Lonkeu, C. Martinez-Diaz, L. Novelle Araujo, PwC, Klitou,Demetrius, J. Conrads, M. Rasmussen, and CARSA (2017). *Digital Transformation Scoreboard 2017: Evidence of positive outcomes and current opportunities for EU businesses*.
PwC (2009). “How will supply chains evolve in an energy-constrained, low-carbon world?” In: *Transportation & logistics 2030 series* 1.
Savills Investment Management (2016). *European Logistics: warehousing the future*. Ed. by Savills Investment Management LLP. London.
Schoemaker, P. J. H. (1993). “Multiple scenario development: Its conceptual and behavioral foundation”. In: *Strategic Management Journal* 14.3, pp. 193–213.
Shift2Rail (2017). *Shift2Rail Joint Undertaking (S2R JU): Annual Work Plan 2018 & Budget*.
Singh, M. (2004). “A Review of the Leading Opinions on the Future of Supply Chains: Supply Chain 2020 Project Working Paper”. PhD thesis. Boston, MA: MIT.
Speranza, M. (2018). “Trends in transportation and logistics”. In: *European Journal of Operational Research* 264, pp. 830–836.
*Substantive Justice International Journal of Law* (2018). Vol. 1.
Tello, P. and R. Weerdmeester (2012). *SPIRE Roadmap*.
UNCTAD (2012). *Global trade trends*. Ed. by UNITED NATIONS PUBLICATION.
von der Gracht, Heiko A. and I.-L. Darkow (2010). “Scenarios for the logistics services industry: A Delphi-based analysis for 2025”. In: *International Journal of Production Economics* 127.1, pp. 46–59.
von der Gracht, Heiko A. and I.-L. Darkow (2013). “The future role of logistics for global wealth – scenarios and discontinuities until 2025”. In: *Foresight* 15.5, pp. 405–419.
von der Gracht, Heiko A. and I.-L. Darkow (2016). “”Energy-constrained and low-carbon scenarios for the transportation and logistics industry””. In: *The International Journal of Logistics Management* 27.1, pp. 142–166.
Willigens, S. E. and von der Gracht, Heiko A. (2013). *The Future of the Supply Chain 2020+: Scenarios and Requirements for the Process Industry*. Ed. by msg systems ag. Ismaning/Munich.
Wisskirchen, G., Biacabe, B., Bormann, U., Muntz, A., Niehaus, G., Soler, G. and von Brauchitsch, B. (2017). *Artificial Intelligence and Robotics and Their Impact on the Workplace*.
World Intellectual Property Organization (2004). *What is Intellectual Property?* Geneva, Switzerland.
Yami, Z. (2018). *Supply Chain Complexity – Dealing with a Dynamic System*.
Zhong, R. Y., S. T. Newman, G. Q. Huang, and S. Lan (2016). “Big Data for supply chain management in the service and manufacturing sectors: Challenges, opportunities, and future perspectives”. In: *Computers & Industrial Engineering* 101, pp. 572–591.