Lecture Notes in Logistics

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Logistics and Supply Chain Innovation

Bridging the Gap between Theory and Practice

EffizienzCluster LogistikRuhr

DINALOG
Dutch Institute for Advanced Logistics

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Lecture Notes in Logistics

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Henk Zijm · Matthias Klumpp
Uwe Clausen · Michael ten Hompel
Editors

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Bridging the Gap between Theory and Practice

Springer

Editors
Henk Zijm
Faculty of Electrical Engineering
University of Twente
Enschede, Overijssel
The Netherlands

Uwe Clausen
Institute of Transport Logistics
TU Dortmund University
Dortmund
Germany

Matthias Klumpp
Institute for Logistics and Service Management
FOM University of Applied Sciences Essen
Essen
Germany

Michael ten Hompel
Dortmund
Germany

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Foreword by Minister Melanie Schultz van Haegen

The Netherlands: gateway to Europe. It is this short phrase that underlines the unique position of our country. Our maritime ports in Rotterdam and Amsterdam, for instance, import 536 million tons of goods every year. Most of these are shipped to destinations further inland, traveling by road, rail, or water. Germany as our most important trade partner is a vital destination. Both countries realize that a strong industry cannot survive without a healthy logistics and supply chain sector. Apart from investments in infrastructure as taking place in both countries, innovation in logistics also needs a strong knowledge base.

The fact that Germany and the Netherlands already rank positions 1 and 2 on the World Bank's Global Logistics Performance Index 2014 is no reason to lay back. Faced with a fierce competition, among others from emerging economies, smart innovation has been made a cornerstone of our economic policy, including innovation in logistics and supply chain control.

For that reason, I welcome the initiatives of two of the most important logistics knowledge clusters, the Dutch Institute for Advanced Logistics (Dinalog) and the Effizienzcluster LogistikRuhr in Nordrhein-Westfalen, to join hands and start a long-lasting cooperation—a cooperation which is based on public–private partnership programs in which industry and academic institutes closely work together to the benefit of our industrial and logistics sectors.

In June 2014, a cooperation agreement was signed at the Fraunhofer Institut für Materialfluss und Logistik, attended by King Willem Alexander and Queen Maxima of the Netherlands, as well as the Ministerpräsidentin Hannelore Kraft of Nordrhein-Westfalen. This book is a first proof of the fact that such a cooperation bears fruit. It shows the richness and versatility of the logistics domain but above all it demonstrates that real logistics innovation can be achieved, when all partners are willing to join hands. I welcome the publication of this book and I sincerely hope that it may serve as a source of inspiration to both students and logistics practitioners.

Melanie Schultz van Haegen
Minister of Infrastructure and the Environment
The Netherlands

Foreword by Minister Michael Groschek

This book contains exemplary and innovative contributions regarding the state of the art in logistics research as well as practice, all aiming at improving the contemporary processes in supply chains. This is very important for economic development in general—and especially so for the two involved regions, home of the two leading research clusters DINALOG and EffizienzCluster LogistikRuhr, as the Netherlands and especially North Rhine-Westphalia play a crucial role in the overall setup of global and European logistics concepts.

As incorporated with this book, the two regions—awarded the leading ranks also in the World Bank global Logistics Performance Index—are complementary regarding global seaports as well as excellent Hinterland connections and value-added services in integrated and resilient logistics concepts.

The state of North Rhine-Westphalia has supported the development of the logistics sector on a concept level as well as at important locations such as Duisburg, Cologne, or Dortmund in the best possible manner, as it features Europe's largest inland port, the third largest German cargo airport as well as leading logistics research facilities as the University of Duisburg-Essen and the Fraunhofer Institute for Material Flow and Logistics in Dortmund.

In order to further strengthen the existing logistics excellence, our state is prepared and motivated to provide further support. This is implemented for example with the new ERDF program with the specific cluster support for "mobility and logistics." This competition for the funding of innovative ideas in logistics was started in April 2015 and has submission options in 2015 and 2016.

Logistics researchers, entrepreneurs, and their partners in industry and commerce within our state and beyond proceed to strive for exceptional results in building the supply chains of the future and providing sustainable as well as resilient and responsible services to our society.

Düsseldorf
July 2015

Michael Groschek
Minister for Building, Housing
Urban Development and Transport
of North Rhine-Westphalia

Preface

In today's global economies, logistics has been recognized as one of the key factors that determine the competitive position of both individual corporations and industry-based networks. At the same time, the very nature of supply chains and supply networks is changing rapidly, as a result of both technological and social developments. These developments include advances in ICT and industrial automation (sensors, robotics, 3D printing, and smart mobility) but also environmental concerns (scarcity of natural resources, carbon emission, and congestion) and finally new business models (e.g., e-commerce). The incorporation of these new technologies' potential in modern supply chain operations, while at the same time addressing environmental and societal concerns, is a formidable challenge for companies, economic clusters, and nations. But a challenge that has to be met: The importance of logistics as an indispensable factor of economic development is undisputed, as evidenced also by the annual publication of the World Bank Logistics Performance Index.

Innovation in logistics and supply chain management is a key to respond to the challenges outlined above. Such innovation requires intensive collaboration of industry and research and education institutes, to translate technological developments into sound business models and to train tomorrow's logistic engineer. For Germany and the Netherlands, the two focal innovation clusters are the Dinalog cluster and the EffizienzCluster LogistikRuhr. The editors of this book have ample experience in conducting projects that aim at the implementation of concepts and ideas in the day-to-day business environment (practicality gap). They also concluded there is a strong need in industry to understand the fundamentals of topics such as sustainable logistics, ICT integration, and Web-based businesses (theory gap).

From these experiences, the basic idea for this edited volume was born: to present state-of-the-art advances in logistics theory in different fields as well as to provide case studies for successful and promising logistics applications within important innovation areas in modern logistics management as best practice. This book reports on a number of studies carried out (and still ongoing) in the Dinalog cluster and the EffizienzCluster LogistikRuhr, bringing together different perspectives of basic and applied research. Above all, it should serve to inform the broader logistics and supply chain sector on what can be achieved by implementing novel and smart innovative ideas and what is needed to make these implementations successful.

In order to support this approach of bridging theory and practice in modern logistics, a selected portfolio of theory outlines, practical examples and case studies and in particular project reports or knowledge management documentations within different areas of logistics and supply chain planning is presented in this volume. The editors have selected contributions from a wide variety of projects carried out in the Dinalog cluster and the Effizienzcluster LogistikRuhr. Contributions are grouped into five main parts, each representing key domains in the evolution of logistics and supply chain management:

(A) Logistics innovation and sustainability;
(B) Urban logistics;
(C) Value chain management;
(D) IT-based innovation; and
(E) Logistics training and knowledge management.

Within each part, important topics are outlined and demonstrated through their application in a variety of case studies. This book is intended for both researchers and practitioners in the field of logistics and supply chain management, to serve as an important source of information for further research as well as implementation in practice and hence to stimulate further innovation.

The five parts are preceded by an introductory chapter by Henk Zijm and Matthias Klumpp. After a brief historical overview and a discussion of the need to design more sustainable supply chains, they list chances and opportunities and also discuss an approach advocated by the European Technology Platform for Logistics ALICE. The paper is completed with a discussion on training and competence management in logistics, including a preview on what may be expected.

Subsequently, Part I outlines *basic concepts and strategies* for sustainable and green logistics based on research and the implementation of new developments. Martijn Mes and Maria Iacob outline an approach of synchromodal transport planning in order to optimize transportation in light of greening the supply chain ("Synchromodal Transport Planning at a Logistics Service Provider"). In "DAVINC^{3}I: Towards Collaborative Responsive Logistics Networks in Floriculture", Jack van der Vorst, Robert Ossevoort, Marlies de Keizer, Tom van Woensel, Cor Verdouw, Edwin Wenink, Rob Koppes, and Robbert van Willegen describe research the results of a large research project on the development of a collaborative logistics network in the floriculture industry as a very high-value as well as high-quality example in terms of innovative logistics. In a larger perspective, sustainable multimodal hinterland networks, including the concept of extended gates, are discussed as a major approach toward green and cost-effective logistics by Albert Veenstra and Rob Zuidwijk ("Towards Efficient Multimodal Hinterland Networks"). Thomas Kjaergaard, Martin Schleper, and Christoph Schmidt suggest in "Current Deficiencies and Paths for Future Improvement in Corporate

Sustainability Reporting" that corporate sustainability reporting should be in the center of attention and management action in order to really achieve sustainable logistics. In an operational perspective, Simon Thunnissen, Luke van de Bunt, and Iris Vis are outlining the logistics impediments and chances of the use of LNG as a fuel for both the transport and maritime sector ("Sustainable Fuels for the Transport and Maritime Sector: A Blueprint of the LNG Distribution Network"). The final contribution in Part I comes from Raphael Heereman von Zuydtwyck and Holger Beckmann in "Efficiency Optimization for Cold Store Warehouses Through an Electronic Cooperation Platform", in which they discuss a specialized but promising approach regarding the use of online cooperation in cold store warehousing in order to reduce the environmental impact of this important section of transportation.

Parts II and III outline different levels of the logistics chain and optimization perspective. Whereas Part II deals with the local level in *urban logistics* concepts, Part III addresses the global level of *value chain design* and optimization. In Part II, challenges, failures, and successes of urban freight transportation are discussed by Goos Kant, Hans Quak, René Peeters, and Tom Van Woensel ("Urban Freight Transportation: Challenges, Failures and Successes"). In "The Role of Fairness in Governing Supply Chain Collaborations—A Case-Study in the Dutch Floriculture Industry", Robbert Janssen, Ard-Pieter de Man, and Hans Quak provide an insight into the impact of fairness considerations on local transport regimes in the floriculture industry. A further important aspect of urban logistics is last-mile parcel distribution, increasing steadily with e-commerce—and therefore the contribution of Theodoros Athanassopoulos, Kerstin Dobers, and Uwe Clausen is a welcome contribution that suggests options to reduce its environmental impact ("Reducing the Environmental Impact of Urban Parcel Distribution"). In "Order Fulfillment and Logistics Considerations for Multichannel Retailers" of this part, Kees Jan Roodbergen and Inger Kolman present a framework for decision making on order fulfillment and logistics in multichannel retail distribution.

In Part III, attention is paid to maintenance and service logistics. Maarten Driessen, Jan Willem Rustenburg, Geert-Jan van Houtum, and Vincent Wiers develop control structures for integrating decision making on inventory control and repair shop control for rotable spare parts ("Connecting Inventory and Repair Shop Control for Repairable Items"). In "Knowledge Lost in Data: Organizational Impediments to Condition-Based Maintenance in the Process Industry", Ronald van de Kerkhof, Henk Akkermans, and Nils Noorderhaven present a pilot study on the introduction of condition-based maintenance in the process industry, as a tool to increase asset availability. Jan Willem Rustenburg discusses the merits of a control tower approach for spare parts management as a radical new business model in "Planning Services: A Control Tower Solution for Managing Spare Parts". Finally, in "Impediments to the Adoption of Reverse Factoring for Logistics Service Providers", Christiaan de Goeij, Alexander Onstein, and Michiel Steeman focus on the adoption of supply chain finance methods, in particular reverse factoring, by suppliers in the logistics service businesses, as a tool to enhance chain liquidity.

Part IV is dedicated to the *information technology* enhancements driving many innovations in logistics and supply chain management. In "Towards an Approach for Long Term AIS-Based Prediction of Vessel Arrival Times", Alexander Dobrkovic, Maria Iacob, Jos van Hillegersberg, Martijn Mes, and Maurice Glandrup address how automatic information system data can be used to accurately predict vessel arrival times and thereby optimize logistics. More generally, the use of information technology as a tool for supply chain design, integrating various formerly isolated modules, is discussed and illustrated with case examples by Matthias Parlings, Tobias Hegmanns, Philipp Sprenger, and Daniel Kossmann in "Modular IT-Support for Integrated Supply Chain Design". Even more into current information technology research is the use of multi-agent systems, i.e., in transport coordination as presented by Frank Arendt, Oliver Klein, and Kai Barwig ("Intelligent Control of Freight Services on the Basis of Autonomous Multi-agent Transport Coordination"). Also the supply chain-wide implementation of RFID is still on the table for logistics innovation and value optimization as Kerem Oflazgil, Christian Hocken, Fabian Schenk, Oliver Teschl, Thorsten Lehr, Mareike de Boer, Christoph Schröder, and Rainer Alt outline in "Smart.NRW—RFID as Enabler for an Intelligent FMCG Supply Chain". The need to improve compliance to external regulations (e.g., customs) in supply chains, without delaying the flow more than necessary, presents a further challenge to smart information system design as Melissa Robles, Juan Diego Serrano, Maria Laura Maragunic, and Bernd Noche argue in "Developing Support Tools for Compliance in Supply Chains". A logistic assistance system to support quality control and quality management for logistic processes is presented by Markus Zajac and Christian Schwede ("Cross-Process Production Control by Camera-Based Quality Management Inside a Logistic Assistance System"). The last contribution of Part IV, "Logistics Mall—A Cloud Platform for Logistics" by Damian Daniluk, Maren Wolf, Oliver Wolf, and Michael ten Hompel, discusses the logistics mall, an approach for a domain-specific cloud platform for the trading and usage of logistics IT services and logistics processes.

Last but not least, the final Part V highlights the importance of *competencies and knowledge management for logistics* in bringing most innovation and technology approaches to full fruit. Therein, an approach for problem-oriented knowledge management in logistics is discussed by Natalia Straub, Christoph Besenfelder, and Sandra Kaczmarek ("Problem-Oriented Knowledge Management for Efficient Logistics Processes"). In "Logistics Qualification: Best-Practice for a Knowledge-Intensive Service Industry", Matthias Klumpp is providing an overview regarding measurement concepts as well as political initiatives directed toward best-practice approaches in logistics training and education. Finally, in "Serious Games for Improving Situational Awareness in Container Terminals", Alexander Verbraeck, Shalini Kurapati, and Heide Lukosch discuss the concept of situational awareness at container terminals as a basis for online (re)planning; they have developed various serious gaming-based instruments that have proven their value in the training of both students and practitioners in industry.

We would like to stress that many contributions include pilot or case studies at a large spectrum of industrial companies, which therefore essentially contribute to the objective of this volume: to bridge the gap between theory and practice in logistics and supply chain management. At this place, we extend our appreciation to their willingness to share current processes and data and to jointly work with academic partners toward improving business processes. But most of all, we are grateful to all the authors for their highly valued contributions; working with them was a rewarding experience. Finally, we express the hope that the projects discussed in this book may be of interest to practitioners in industry as well as to industrial engineering and logistics students, and that they may serve as a source of inspiration for further research. We look forward to the further application and implementation of the innovative concepts presented in this volume in industry.

June 2015

Henk Zijm
Matthias Klumpp
Uwe Clausen
Michael ten Hompel

Collaboration Agreement: Signing Ceremony

On May 27, 2014, the Effizienzcluster LogistikRuhr and the Dutch Institute for Advanced Logistics (DINALOG) signed an agreement to jointly work on logistics and supply chain innovation, in close collaboration with industries and the logistics sector in Germany and the Netherlands. The signing ceremony was attended by their Majesties King Willem Alexander and Queen Maxima of the Netherlands, the Prime Minister of North-Rhine Westphalia, Mrs. Hannelore Kraft, The Minister of Economic Affairs of the Netherlands, Mr. Henk Kamp, and the Mayor of Dortmund, Mr. Ulrich Sierau.

At the table (from left to right):

Mr. Willem Heeren, Chairman of the Board of the Dutch Institute for Advanced Logistics
Prof. Dr. Michael ten Hompel, Chairman of the Board of the Effizienzcluster LogistikRuhr

Standing behind the table (from left to right):

Mr. Henk Kamp, Minister of Economic Affairs, the Netherlands
Dr. Thorsten Hülsmann, Director of the Effizienzcluster LogistikRuhr
Mr. Ulrich Sierau, Mayor of Dortmund
Mrs. Hannelore Kraft, Prime Minister of the State of North-Rhine Westphalia
His Majesty King Willem-Alexander of the Netherlands
Her Majesty Queen Maxima of the Netherland
Prof. Dr. Henk Zijm, Scientific Director of the Dutch Institute for Advanced Logistics

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Logistics and Supply Chain Management: Developments and Trends

Henk Zijm and Matthias Klumpp

Abstract The demand for sustainable logistic and supply chain processes poses enormous challenges in terms of technology integration, the development of new business models, cultural change and job qualification, and as such requires a real paradigm shift. In this paper, we start with a brief sketch of how modern logistics and supply chains emerged as a result of diversification and specialization of industrial production, globally scattered availability of resources and more demanding consumer markets. Jointly with advances in freight transport and communication technologies, these developments have led to the global economy we face today. The strong growth of trade and consumption however also revealed some essential weaknesses of the system that renders current practices in the long run unsustainable—in social, environmental and economic terms (people, planet, profit). Future supply chains should no longer deplete scarce natural resources or contribute to climate change, should avoid environmental pollution and withstand safety and security threats, while at the same time remaining competitive and satisfying high labor quality standards. This requires not only the application of advanced technologies to mitigate or even neutralize these negative effects, but also the development of smart business models, new job qualification standards and corresponding (lifelong) training and education programs at all levels, including artificial intelligence based learning.

Keywords Logistics · Global supply chains · Sustainability · Circular economy · Physical internet · Logistics education · Logistics trends · Artificial intelligence

H. Zijm (✉)
Dutch Institute for Advanced Logistics, Breda, The Netherlands
e-mail: w.h.m.zijm@utwente.nl

H. Zijm
University of Twente, Enschede, The Netherlands

M. Klumpp
FOM University of Applied Sciences, Essen, Germany

M. Klumpp
University of Duisburg-Essen, Essen, Germany

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1 Supply Chains: Definition and a Short History

A supply chain concerns the entire production and distribution chain from raw materials to final customers and on top of that the return flow of products and possible re-use of materials or components (closed loop supply chain). Almost always, such a production and distribution chain is not executed by one industry but instead encompasses a number of companies and organizations jointly operating in a chain or network. This so-called end-to-end supply chain is represented in the Supply Chain Operations Reference (SCOR) model, see Fig. 1 (Poluha 2007; Simchi-Levi et al. 2008).

Current supply chains often span the entire globe and involve production, trade and logistics organisations around the world. For instance, in many European countries, most solid materials products and a significant percentage of food products are not produced in the region or country of use or consumption but elsewhere, not seldom even at other continents. In this paper, we investigate why worldwide production and—as a consequence—worldwide logistics flows have become so dominant, what their merits are but also why current practices in the long run are not sustainable, either in social, environmental or economical terms. To turn the tide, a fundamental rethinking of the way we organise production and logistics as well as logistics information management and education is needed. To understand this paradigm change, we first briefly review the way current production systems evolved, see also Hopp and Spearman (2008).

1.1 The First Industrial Revolution: The Principle of Labor Division

In 1776, the English economist Adam Smith published his "*An inquiry into the nature and causes of the wealth of nations*", in which he explained in detail the merits of what has become known as the "principle of labor division" and clearly demonstrated the productivity gains that could be achieved by systematically exploiting the learning curve (Smith 1776). That publication marked the start of the dominant philosophy of efficiency through specialization, worked out towards a first theory on production organisations by Charles Babbage (who later became known as the father of the digital computer) in his "*On the Economy of Machinery and Manufactures*" (Babbage 1835). The first industrial revolution, initiated by the invention of the steam engine, or rather its application in industrial production as engineered by James Watt, meant the definitive change from the classical domestic system and the craft guilds to mass production and mechanization, which has dominated production ever since. Mass production requires physical concentration and so the massive factories were born that colored the industrial landscape in the 19th and large parts of the 20th century. Ideas of mass production were governing the development of the steel industry by Andrew Carnegie, the large food

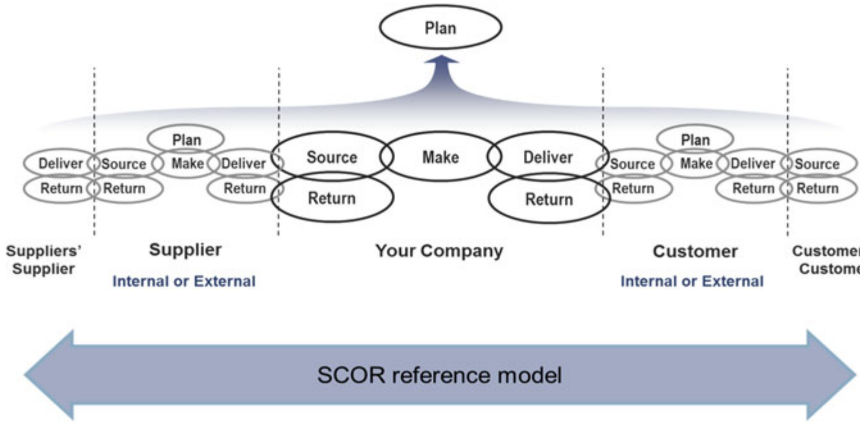

Fig. 1 SCOR model of end-to-end supply chains (*Source* Supply chain council)

conglomerates, the automotive sector and so on: scale, not scope was the leading paradigm. Famous became the reply of Henry Ford to the question in what color the T-Ford was going to be produced and customers might choose from: "Any color, as long as it's black". It was also the time in which the first scientific management theories were developed, with Frederick Winslow Taylor, now often viewed as the first industrial engineer, as its most famous representative. His work on time and motion studies, best working practices and in particular the differential piece rate system, was followed by pioneers such as Frank and Lilian Gilbreth, and Henry Gantt, who introduced the Gantt Chart in project management, while a first attempt to systemize quality management was developed by Walter Shewhart through his work at Bell Labs on Statistical Quality Control methods.

Mass production and limited product diversity continued to be the name of the game, also during the first decades after the Second World War. There was a shortage of the most basic goods; everything that could be made could be sold. However, starting with the sixties, as prosperity grew, consumers began to demand larger variety, leading to more complex products. In response, manufacturing industries introduced more versatile machines that could produce a variety of products, albeit at the cost of large setup or changeover times. The result was still production in large batches: economy of scale remained the leading philosophy. Also, the transfer of production to low wage countries in the Far East and Southern America was an attempt to sustain mass production at affordable costs. Efficiency also marked modern logistics: the introduction of the container and modern materials handling systems meant a big step forward in processing the ever growing logistics and material flows. Functional specialization, concentration of mass production in large factories, the shift of routine production to low wage countries, and as a result supply chains that tend to grow longer and longer, marked the industrial landscape still in the seventies and eighties of the preceding century.

1.2 From Mass Production to Flexible Manufacturing and Logistics

The two oil crises of 1973 and 1979 for the first time revealed also the weaknesses of the prevalent production philosophy. Raw material prices and interest rates raised sharply and industrial companies started to realize that long supply chains represented large amounts of stock and hence capital invested; besides, long supply chains make it hard to quickly adapt to changing market demand. Companies were inert, and not prepared for the flexibility that a changing society required. In addition, publications such as “Limits to Growth” from the Club of Rome (1972) stressed the depletion of natural resources and the pollution of our natural environment at an exponentially increasing rate (Meadows et al. 1972). For the first time industry and the public started to realize that current supply chains were to become economically prohibitive, and socially unacceptable.

And so, large scale batch production once applauded as the most efficient production philosophy now became the cause of all evil. Fortunately, new technologies proved to be at least a partial remedy. The introduction of flexible manufacturing systems, often based on computerized (CNC) machining and robotized assembly, helped to balance efficiency and flexibility, not only in production but also in the nodes of logistics networks, i.e. the material handling and distribution centers. In addition, attempts were made to synchronize and integrate supply chains by means of administrative information systems such as MRP and ERP, or by introducing new production philosophies such as Just-in-Time, or lean and agile manufacturing that focus on rigidly removing any buffer stocks as these were primarily seen as indications of waste or slack that characterize non-synchronized production. These were the heydays of the Toyota Production System and the SMED (Single Minute Exchange of Die) system, an engineering philosophy advocated by Shigeo Shingo, who systematically sought to reduce machine setup or changeover times, thereby again aiming at flexible, synchronized manufacturing and logistics (Shingo 1985).

Hence, although factories became more flexible, long and expensive supply chains due to functional specialization and dispersed production of parts and components continued to be the overarching story. At the same time, these supply chains contribute significantly to the BNP of those countries for which logistics is a strong economic sector, including Germany and The Netherlands (which ranked positions 1 and 2 on the World Logistics Performance Indicator 2014, published by the World Bank). The unprecedented growth of production and logistics and its far reaching rationalization as a result of modern manufacturing methods, the introduction of the container and above all the penetration of automation and computing technologies is definitely one of the sources of prosperity in most developed countries.

But this growth comes with a price and more and more it is realized that current supply chains are fundamentally unsustainable. This will be outlined in the next section.

2 Unsustainability of Today's Supply Chains

Current production and logistics systems cause serious and in the long run unacceptable environmental damage, due to for instance the emission of hazardous materials (CO_2, NO_x, particulate matter), congestion, stench, noise and more general the high price that has to be paid in terms of infrastructural load. While the European Committee has set clear targets to reduce Greenhouse Gas Emissions (GGE) in 2015 to 60 % as compared to 1990, the percentage of transport related GGE has increased from 25 % in 1990 to 36 % today (ALICE 2014). Besides, the pressure of the infrastructure needed on land use gives rise to additional social and environmental problems which hit urban areas in particular. Below, we first describe various phenomena which sometimes represent threats but in all cases pose at least important challenges to future supply chain management. In Sect. 3, we list ways and developments that may help to address these challenges.

2.1 Scarcity and Sustainability

Natural resources are scarce and not evenly distributed in terms of type and geographical location in the world. Logistic chains enable the distribution of materials, food and products from the locations where they are extracted, harvested or produced to people's homes and nearby stores. Current supply chains and logistics systems are global, partly due to natural conditions but certainly also because of labor rate differences between emerging and mature economies. First indications of reshoring production however become visible, not only because wage rates are moving upwards also in a number of Far-Eastern countries, but also since the amount of manual labor needed in high tech products continues to diminish, while logistic costs are increasing. As a result, future supply chains are believed to be "*glocal*"*: global when needed, local when possible*. On the other hand, global supply chains will remain inevitable in cases where conditions for growing food ingredients are only satisfied in some regions in the world, or when minerals are only locally available. They will also continue to exist in cases where material processing consumes such an immense amount of energy that this is only sustainable at places where energy is abundantly and sustainably available, such as locations with geothermic energy, locations with water-powered energy generation, and locations with long periods of sunshine.

2.2 Demographic Trends

The current world population of 7.2 billion is projected to increase by 1 billion over the next 12 years and reach 9.6 billion by 2050, according to a recent United

Nations report (LOG2020 2013). Within Europe, population size is predicted to be stable—but a severe shift in population movements is expected from Eastern to Western Europe. Ageing continues, meaning that people in general will work longer in order to maintain a reasonable standard of living. Europe-based companies should be prepared for scarcity of human resources and should be able to provide working conditions that extend the working life of employees. The need to further increase productivity while at the same time diminishing the ecological and social footprint, requires a quality upgrade of the human resource pool, e.g. by better education and training, including lifelong learning programs. In parallel productivity can be improved by better support tools, easier access to relevant information, and finally further automation of both technical processes (i.e. robotics) and decision making (i.e. artificial intelligence).

2.3 Urbanization

As urbanization continues[1] it becomes an unprecedented challenge to keep cities livable, which includes a sustainable logistics planning and execution. The development of wealth in Asia and Latin America has resulted in a huge shift from agricultural and nomadic forms of living to urban life. More and more cities with over 10 million inhabitants will emerge requiring different modes of transport and logistics systems than available today. There is an increasing interdependency between supply chain design or management and urban planning or land-use management. It is not yet clear whether mega cities are sustainable when wealth increases to the levels currently accessible for the population in developed countries. Innovative sustainable, safe and secure logistics might inspire agencies and institutions towards new patterns of sustainable urbanization.

2.4 Supply Chain Safety and Security

Border-crossing supply chains and logistics systems often concern high-value goods, and therefore are vulnerable to crime and illicit acts. Within the European research programs, various projects have developed roadmaps to enhance supply chain safety and security. Regarding safety, extensive attention has been paid to safe working conditions (and for instance driving hour regulations) but the fight for supply chain security, abandoning crimes and illegal activities, appears to be a harder one. Economic crimes for example include: theft (robbery, larceny,

[1]In 2007 the world passed the point in which more than half of its population is living in urbanized areas, in some developed countries the urban population percentage is well above 70 %, and continues to rise.

hijacking, looting, etc.), organized immigration crime (human trafficking, illegal immigration), IPR violations and counterfeiting and customs law violations (tax fraud, prohibited goods). Alternatively, ideologically or politically motivated crimes occur, next to obvious vandalism (Hintsa 2011). A legislative framework may in principle safeguard society against these unwanted practices and provide a mandate for government authorities to act. However, the challenge often is to find a balance between required inspections and interventions, and the economic interests of shippers and logistic service providers who wish to minimize delays, inefficiencies and additional costs.

Another aspect of supply chain security is supply chain resilience, which can be defined as the ability to maintain, resume, and restore operations after a major disruption (Gaonkar and Viswanadham 2007). This is a critical aspect of supply chain risk management and is generally seen as one of the major future challenges. Disruptions to supply chains can prove costly, as highlighted by a variety of natural disasters. According to research conducted by Accenture, significant supply chain disruptions have been found to cut the share price of impacted companies by 7 % on average (WEF/Accenture 2013).

2.5 Changing Consumer Markets

Commercial product life cycles tend to become still shorter. At the same time we observe an increased re-use of products, components and materials, both via (electronic) second markets and in so-called closed-loop supply chains (cradle-to-cradle, circular economy). Mass customization is an important aspect of current consumer markets, enabled by fast technological developments (to be discussed below). The rapid advance of e-commerce is another characteristic of today's markets: on the one hand it reduces the number of links in the supply chain, but without adequate regulation of both forward and reverse flows of packages it often leads to a rapid additional increase of urban congestion and pollution. Finally, we note that in some sectors customers no longer buy an actual product but only the service the product represents (e.g. cloud computing, music streaming, car sharing). These phenomena will have a profound impact on the ecological footprint of mankind and as such also on the design and planning of future supply chains.

All phenomena sketched above pose important challenges to future supply chain design, planning and control. Fortunately, technological innovations are extremely helpful to at least partially address some of these challenges. But technological innovation alone is only a part of the story; at least equally important are the development of smart and fair business models based on joint responsibilities and fair allocation of revenues instead of on individual profit maximization, and the mind shift needed for all stakeholders concerned, which in turn requires high investments in (lifelong) training and education programs (cf. Sect. 4).

3 Chances and Opportunities for Future Supply Chains

The observations outlined in the preceding section call for a fundamental paradigm change when redesigning future-proof supply chains, i.e. supply chains that are able to efficiently deliver goods and services when and where needed, while respecting social and environmental constraints. Fortunately, both technological and social-economic innovations provide adequate tools that may help to address that challenge.

3.1 New Materials and Manufacturing Technologies, Design for Logistics

The design of new and lightweight (bio-)materials and their application in a wide variety of products poses exciting new possibilities to diminish both the costs and ecological footprint of these products. Rapid advances in such fields as polymer technology, bio-engineering and nanotechnology already lead to products that could not have been imagined only 10 years ago. Technologies like 3D-printing and micro-machining are also a step forward towards mass-customization but in addition have a profound logistic impact, for instance in stimulating "local for local" production. In addition, 3D printing which is believed to have a future in particular in small batch and one-of-a-kind manufacturing, may lead to far shorter lead times and hence a reduction of so-called anticipation (safety) stocks, because it allows production at the place and time needed. Another manifestation of improvement through technology is the continuous development of cleaner engines and non-fossil fuel based engines (e.g. electric, hybrid or LNG-powered vehicles for city distribution and local passenger transport, but also for both inland and sea vessels as an attempt to diminish the environmental footprint. It is important to realize the importance of an integrated supply chain view when focusing on reducing their negative impacts. As an example, consider product design. Modular product design allows the transport of components instead of full products which not only results in a higher package density but in addition again allows customization closer to the end-user. Also note that that 3D-printing and additive manufacturing in general is based on material addition, instead of material removal as in classical machining, hence in principle has a waste avoidance potential. Smart packaging logistics also may help to reduce volumes and to avoid waste, in particular in the case of bio-degradable package materials.

3.2 Automation and Robotics, Internet of Things

The impact of robotics has already been visible for a long time e.g. in automotive assembly lines but also in warehouses and distribution centers, in so-called ASRS

(Automatic Storage and Retrieval Systems), often consisting of high bay storage racks which are served by fully automated cranes, and equipped with automatic identification, i.e. RFID technology. Apart from the visible hardware, innovative warehouse management systems help to coordinate and synchronize activities, in close communication with information systems covering both suppliers and customers. Similar developments can be found at container terminal sites in both seaports and inland harbors. Without exception, all such systems rely heavily on smart sensor and actuator systems, recently evolving towards the so-called Internet of Things, where devices are equipped with sensors that automatically signal when actions such as ordering or replenishment have to be initiated. Additionally, materials and machinery themselves are able to communicate with each other and find solutions based on decentralized and autonomous decision making using state-of-the-art algorithms. In particular the world of both passenger and freight transport is currently innovating rapidly, as demonstrated for instance by various experiments with freight vehicle platooning, in which a convoy of freight trucks is controlled by a single driver. Vehicle transportation in 2050 is foreseen to be largely unmanned transportation.

3.3 Business Information Systems, New Business Models

Although many scholars view business information systems and architectures as belonging to the field of technology development, it is essentially more than that. Complex modern supply chains are first and foremost characterized by the fact that many stakeholders are involved in shaping its ultimate manifestation. Direct stakeholders are of course suppliers of raw materials, product designers, manufacturing and trading companies, logistics service providers, forwarders and transport companies, and ultimately the customer. Indirect stakeholders are supply chain financiers, ICT consultants, local and regional governments in their role as infrastructure providers but also as representatives of societal interests, customs authorities and indeed the public at large. The multi-stakeholder and multi-decision maker environments we deal with require adequate mechanisms to respond to their requirements, including distributed architectures, cloud computing solutions, cognitive computing and agent-based decision support systems. Organizational innovations are indispensable to fully exploit the potential of advanced information and decision support architectures. The recent attention for data driven models (big data analytics) marks an important further step towards full-blown automated decision architectures.

The design and acceptance of decision models based on both horizontal and vertical cooperation in supply networks however proves to be one of the most difficult steps to make. Although many stakeholders quickly recognize the potential win-win situation arising from collaboration they find it in general extremely hard