Rico Merkert · Kai Hoberg *Editors*

Global Logistics and Supply Chain Strategies for the 2020s

Vital Skills for the Next Generation

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We dedicate this book to
Prof. Dr. h.c. Klaus-Michael Kühne,
in celebration of his 85th birthday and in recognition of his lifetime contribution to the global logistics industry. With over 60 years as a champion of his field, he is a role model as an exceptional benefactor who has furthered the cause of academia to enrich practice in supply chain management and logistics.
—Prof Rico Merkert and Prof Kai Hoberg

Foreword

Business schools around the world have long known the value of teaching global logistics and supply chain management (GL&SCM). This is both a sector and a field of study with an exciting and challenging international management dimension. While it is true that freight moves the world, it is also the case that the GL&SCM sector has evolved dramatically in recent decades. It has experienced both disruption and groundbreaking innovation—the latter often arising from the sector's partnership with universities like ours. Logistics and supply chain management has traditionally focused primarily on transportation and warehousing, but today encompasses many different activities that enable the seamless orchestration of material, financial, and information flows. Companies combine their own resources with those of partners and third parties and leverage complex networks to produce, ship, and distribute their goods across the globe in ways unimaginable just twenty years ago.

The past decade has seen continuous progress and dramatic improvements in global supply chains and logistics that have benefited all stakeholders. End customers can take advantage of new innovative products that are offered at high service levels and low lead times. Companies can draw from a huge portfolio of suppliers across the globe to leverage their specific skills and benefit from low costs. Suppliers can better align their manufacturing schedules with the actual needs of their direct customers based on just-in-time and just-in-sequence principles. Logistics service providers can use their end-to-end visibility in shipping schedules and capacities to select the most appropriate carriers.

Efforts to optimize supply chain processes continued to bear fruit until the early 2020. The emergence of the COVID-19 pandemic, however, changed all our lives: personally and professionally. The pandemic had dramatic consequences for global supply chains. It also underlined the fact that global supply chains are the backbone of many industries and economies. Suddenly, supply chains were in turmoil. We saw unprecedented stockouts and delays everywhere—in Sydney, in Hamburg, and across the globe. Consumers had to confront the reality of empty toilet paper or pasta shelves in supermarkets. Automotive plants were shut down due to a lack of parts. Ports were congested and overwhelmed due to the backlog of containers arriving at the same time.

What is now evident is that there is still much work to be done by companies to optimize their logistics and supply chain activities. It is also clear that this will not occur without the right logistics and supply chain skills. But that only begs the question: what are the “right” skills? From a business school perspective, this question can be reframed in these terms: in a world of increasing automation, rising concern about sustainability, and rapidly changing ecosystems, what are the skills and qualities that business schools should seek to instill in their graduates wanting to pursue careers in global logistics and supply management?

One of the many contributions of this book is that it helps to address this question. In addition, for those who are seeking to become the next generation of leaders in global logistics and supply chain management, this book draws on the accumulated wisdom of the most renowned scholars in the field to provide insights into the sorts of strategies that future talent might employ.

This book, then, is timely. It is a must-read for anyone interested in a career in this sector. We are very proud that Professors Rico Merkert and Kai Hoberg brought together such a large and impressive international team of globally recognized academics and leading senior managers to contribute to this book. What could be better for graduates and young professionals than hearing from the horse’s mouth or, in other words, experts in all the different disciplines that today are considered global logistics and supply chain management?

Of course, it is not just the academics who have contributed to this book but also the ecosystems that business schools, such as KLU and the University of Sydney Business School, provide. We train talent to unlearn old habits, to think strategically, and to turn challenges on the horizon into opportunities that will result in value for businesses and wider communities and, of course, a successful career for those who are brave enough to set out on one of the most exciting industries of this and future decades. The first step into that successful future is to read this important book.

Dean, The University of Sydney Business School — Professor Greg Whitwell
Sydney, Australia
President, Kühne Logistics University — Professor Thomas Strothotte
Hamburg, Germany

Preface

Global logistics and supply chain management have evolved in the past few decades from an unpopular and often neglected area to a field that is widely seen as a key enabler of business success. Especially, during the COVID-19 pandemic but also due to disruptions and rising costs in many supply chains, global logistics and supply chain management have not only been rediscovered as a vital sector for many industries and entire economies but also as an industry that is fun and financially worthwhile to start a career in.

In the next decade, it will become even more critical to design the right logistics and supply chain strategies given potential challenging and disruptive economic, technological (i.e. automation), and sustainability developments. Economic developments such as the further growth of Asian markets increased political friction across the globe leading to a reversal of globalization (on- and sure-shoring) and strong interest in omnichannel retailing will all require managers to re-shape, refocus, and potentially re-invent their entire supply chains. New technologies such as the Internet of Things, digital manufacturing, or blockchain are emerging quickly and could provide competitive advantage to those companies that leverage the technologies smartly while managers that do not adopt and embrace change could be left behind. Last but perhaps most important for mankind, sustainability aspects such as low-carbon transportation, closed-loop supply chains, or socially responsible supply chain set-ups will become essential to operate successful in the future.

All these aspects will affect global logistics and supply chains as a whole and also in different functional areas, such as air cargo, maritime logistics, or sourcing/procurement. This book aims to dive into several of these functional topics to highlight the key developments in the next decade predicted by leading global experts in the field. Supply chains will be managed by a new generation of leaders that will need to be equipped with different skills and an innovative mindset that not only embraces but also works hand in hand with technology and algorithms. To prepare this next generation of supply chain leaders in a business school/university environment (produce future proof graduates) as well as in the context of continuing professional development (enhance skill sets of current leaders), this book features contributions and key insights of globally leading scholars and senior industry experts. Their forward-looking perspectives on the anticipated trends are aimed at informing the reader about how global logistics and supply chain management will evolve in the next decade and which graduate qualities and skills will be required to succeed in the “new normal” environment that will be characterized by volatile and increasingly disrupted business ecosystems.

For practitioners and managers, this book aims to offer key insights in terms of what may be the next big thing in this fast-changing industry. For graduates, this book provides tips on what to study and what skills are likely to be needed to start a successful career in logistics and supply chain management. Future scenarios are envisaged to provide both practitioners and students with insights that will help them to adapt and succeed in a fast-changing world.

Sydney, NSW, Australia — Rico Merkert
Hamburg, Germany — Kai Hoberg

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We would like to acknowledge the contribution of the 33 globally recognized academics and 24 senior managers (including their legal departments), as without their support this book project would have not been possible. We are further thankful to the Springer team, in particular Barbara Bethke who has helped us to make this innovative publication format happen at Springer.

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Editors and Contributors

About the Editors

Rico Merkert is Professor in Transport and Supply Chain Management and Deputy Director of the Institute of Transport and Logistics Studies at the University of Sydney Business School. He has taught and researched at several high-profile institutions such as Cranfield University or Haas Business School (UC Berkeley) and is Editor-in-Chief of the *Journal of Air Transport Management*. Rico has been a strategic advisor to boards and C-level management providing deep insights and research related to performance measurement, strategic management, innovation, and supply chain analysis, economic impact, and demand analysis for a range of major logistics, freight forwarding, airline, and airport companies, both in the global and regional context.

Kai Hoberg is Professor in Supply Chain and Operations Strategy and Head of the Operations and Technology Department at Kühne Logistics University, Hamburg. He was a visiting researcher at leading universities such as Cornell University, NUS Business School, Saïd Business School, and the University of Sydney. Before returning to academia, he worked as a strategy consultant and project manager in the operations team of Booz & Company (Strategy &). His current research focuses on supply chain analytics, the role of technology in supply chain management, and inventory management. In his research, he is working with renowned partners like McKinsey & Company, Zalando, Procter & Gamble, or the World Bank.

Contributors

Michael G. H. Bell is the Professor of Ports and Maritime Logistics in the Institute of Transport and Logistics, at the University of Sydney Business School. Prior to this, he was for 10 years the Professor of Transport Operations at Imperial College London and for the last 5 years the Founding Director of the Port Operations Research and Technology Centre (PORTeC). His research and teaching interests span city logistics, ports and maritime logistics, transport network modelling, traffic engineering, and intelligent transport systems. Michael is the author of many papers and books (including *Transportation Network Analysis*, 1997) and is/was an Associate Editor of *Transportation Research B, Maritime Policy & Management*, and *Transportmetrica A*.

Christoph Bode is a full professor at the Business School of the University of Mannheim and holds the Endowed Chair of Procurement. He obtained his PhD from WHU—Otto Beisheim School of Management (Germany) and his Habilitation from the ETH Zurich (Switzerland). Prior to joining the faculty in Mannheim, he served at the Department of Management and at the Center for Economic Research (CentER) at Tilburg University (The Netherlands) and at the Department of Management, Technology, and Economics (D-MTEC) at ETH Zurich. His teaching and research interests lie in the areas of procurement, supply chain, logistics, and operations management with a special focus on risk and disruptions, interfirm relationships, innovation and entrepreneurship, sustainability, and strategies and performance. His research in these areas has been published in multidisciplinary management journals, as well as in leading operations management journals.

Robert N. Boute is a professor of operations management at the Faculty of Economics and Business at KU Leuven and Vlerick Business School. His research focuses on inventory control and supply chain management. Recent works include digital operations, smart logistics, and predictive analytics for service maintenance applications. He was named one of the 40 best professors under 40 by Poets & Quants in 2016, and was laureate of the 2017 Franz Edelman Award for Achievement in Operations Research and Management Sciences.

Davide Burkhart is a doctoral student at the Endowed Chair of Procurement at the University of Mannheim. He holds a master's degree in Industrial Engineering (MSc) from the Technical University of Darmstadt, where he also graduated with a bachelor's degree (B.Sc.). During his studies, he gained international experience in various internships in the automotive industry. He also completed a research internship at the University of St. Gallen where he investigated distributed ledger technologies in supply chains. In his research, he focuses on buyer–supplier relationships and their implications for supply chain transparency and risk management.

Tsan-Ming Choi (Jason) is Professor and Yushan Fellow in the Department and Graduate Institute of Business Administration, National Taiwan University (NTU). He has published extensively in leading journals in the fields of operations management, logistics, and supply chain management. He also serves the profession as the Co-Editor-in-Chief of *Transportation Research Part E*, a Department Editor of IEEE *Transactions on Engineering Management*, a Senior Editor of *Production and Operations Management*, and an Associate Editor of *Decision Sciences*. Before joining NTU in the fall of 2021, he was a "tenured" professor at The Hong Kong Polytechnic University, where he received the prestigious President's Award for Excellent Performance.

Yao Cui is an assistant professor of operations, technology, and information management at the Samuel Curtis Johnson Graduate School of Management at Cornell University. At Johnson, he teaches operations and supply chain management in the Executive MBA and MBA programs. His research interests focus on operations strategies in new business models. Particularly, he studies technology innovation in supply chains, labor management in the gig economy, and revenue management in hospitality industries. Professor Cui's research has been published in leading academic journals. In his research, he works with companies from a variety of industries, such as airlines, car-sharing, logistics, agri-food, and blockchain start-ups.

René de Koster is chair in Logistics and Operations Management and Head of the Technology and Operations Management Department at Rotterdam School of Management, Erasmus University Rotterdam. He holds a PhD from Eindhoven University of Technology. He is the 2018 honorary Francqui Professor at Hasselt University, Belgium. His research interests are warehousing, material handling, terminal operations, and behavioral operations. He is the founder of the Material Handling Forum and is author/editor of 8 books and over 250 papers in books and academic journals. He is on the editorial board of several journals with associate editorships of *Transportation Science*, *Service Science*, and *Operations Research.*

Deborah Ellis has consulted with leading companies for over 25 years on supply chain strategy and network design. Her focus has been on market-focused approaches and developing techniques to directly link the operation to the customer value it generates. Deborah has led global projects for multinationals in the consumer goods, industrial, pharmaceutical, and fashion sectors and industry-level projects in agriculture and mining. She has co-authored, with John Gattorna, *Transforming Supply Chains* in 2020, and contributed chapters on a range of topics including humanitarian logistics and network design. Deborah and her colleague Dr. Gattorna have presented the Global Supply Chain Retreat Series in Australia, Europe, Asia, and South Africa since 2017.

Milad Keshvari Fard is an associate professor at the University of Bath School of Management. His main research interest lies in humanitarian operations, trying to answer the question of how to optimize the use of scarce resources in humanitarian organizations in order to achieve highest welfare for beneficiaries. His research consists of both analytical and empirical aspects. His works in humanitarian operations have been presented in international conferences, and published in leading academic journals such as *Manufacturing & Service Operations Management (MSOM)* and *Productions and Operations Management (POM)*. He is also active in other fields of research such as revenue management and location problems.

Britta Gammelgaard is Full Professor of Supply Chain Management at Copenhagen Business School. Her research has been published in Danish and international scientific journals. She is Editor-in-Chief of *the International Journal of Logistics Management* (IJLM). Before that, she was associate editor for other supply chain management journals and has guest-edited numerous special issues. She has received several awards for her research and research management activities including the prestigious Danish Hedorfs Fond's Transport Research Award. Professor Gammelgaard is vice-chair of the Danish professional association Effektivitet.dk where she is working to get hers and colleagues' research communicated to practice through its magazine.

John Gattorna is one of the most influential voices in the development of contemporary supply chains. The concepts and frameworks he developed over four decades are now used by many leading multinational corporations. John's primary aim has been to put more science behind what was previously regarded as a very operational field. John views supply chains as socio-technical systems, which to be fully effective must align with their target customer base. In 2018, John's contribution to the field was recognized by the CSCMP with the Distinguished Service Award, and induction into the Hall of Fame. He is a prolific author, and holds adjunct professorship at universities around the world.

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Khaled Hussein is Assistant Professor at the College of International Transport and Logistics, Arab Academy for Science Technology and Maritime Transport, Cairo. He has taught logistics and supply chain management modules while having contributed to various academic activities at the College. Khaled has recently obtained his PhD degree at the World Maritime University with the title of "Development of Sustainable Port Supply Chain Integration in Egypt". During his PhD research, Khaled presented a paper at the International Association of Maritime Economists (IAME) conference at Mombasa, Kenya, in 2018. Additionally, he has co-authored a paper in the International Journal of Logistics Research and Applications in 2021. He has hold a keen research interest in such topics as sustainable supply chain management and maritime logistics, in particular, (sea)port sustainability.

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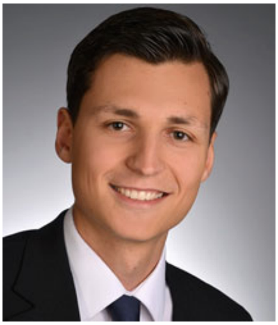

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Radu Palamariu is the Managing Director Asia Pacific & Europe of Alcott Global and the Global Head of Supply Chain and Logistics Practice. He has been working on C-level and top management executive search assignments with Top Fortune 500 companies and local Asia conglomerates, particularly for manufacturing, logistics, transportation, supply chain management, and e-commerce. A frequent speaker at industry conferences across the region, he is a contributor on latest technologies shaping supply chains, as well as human resources trends and developments. He is the host of the "Leaders in Supply Chain" Podcast, which is consistently ranked among the top 10 global industry podcasts. Radu has been featured in *Bloomberg*, *Logistics Insight Asia*, *Bangkok Post*, as well as the *MIT Supply Chain Talent Magazine* and has been named as one of the top 3 Global Supply Chain Influencers on LinkedIn.

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Thomas Knudsen became Managing Director at Toll Group on 1 January 2020, after serving for two years as Toll's President of Global Forwarding. At Toll, Thomas is leading an ambitious strategy to transform Toll into one of Asia Pacific's leading transport and supply chain companies. Thomas is a senior executive with a global logistics career spanning more than 25 years. Thomas has held executive leadership, commercial, trade, and route management roles in the Middle East, North America, Europe, and Asia. Prior to joining Toll, Thomas was CEO, Asia Pacific at global logistics leader, Damco. Based in Singapore, he was responsible for the company's day-to-day business operations for the Asia region, with more than 5000 colleagues in a region stretching from Japan to Myanmar. Prior to joining Damco, Thomas spent two decades with A.P. Moller—Maersk. In his most recent role there, Thomas was the Asia Pacific Regional CEO for Maersk Line. In this role, he led all commercial activities across the region and was a member of Maersk's global leadership team. Thomas holds an Executive Master of Management degree in Supply Chain from IE Business School, Madrid, Spain. Thomas has completed a number of executive programs at Harvard Business School, INSEAD, and Cranfield.

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Adam Radwanski has been SVP & Managing Director Asia Pacific at Silversea Cruises since June 2020 and oversees the strategic direction for the company in the fast-growing APAC region. Adam is an accomplished senior executive with over 13 years of experience in the travel industry, offering a unique blend of strong leadership skills, strategic capabilities, and knowledge. Prior to joining Silversea Cruises, between 2008 and 2020, Adam has worked in several high impact commercial roles at Qatar Airways in Europe, the Middle East, and Australasia. Before joining Qatar Airways, Adam worked at Virgin Atlantic Airways, based in the UK, in sales and distribution roles within Virgin's international sales division. He holds a Global Executive MBA Asia Pacific from UCLA Anderson Business School and National University of Singapore (awarded with C .H. Wee Gold Medal for best graduate), an MA in International Relations from the University of Warsaw, Poland, and an MSc in Air Transport Management from Cranfield University, UK.

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Lars Brzoska studied business at the University of Münster and received his doctorate in economics from that institution in 2003. That same year, he began at the Gildemeister Group, eventually becoming the Managing Director of DMG Vertriebs und Service GmbH. In 2010, Dr Brzoska joined the Demag Cranes AG, later Terex Material Handling & Port Solutions AG, and worked there until 2014, lastly on the Board of Management. In April 2014, Dr Brzoska was elected to the Board of Management of the Jungheinrich AG. He was responsible for the Marketing & Sales division until 2018 and for Technics until 2019. He has been Chairman of the Board of Management of Jungheinrich AG since 2019. Dr Lars Brzoska is married and has two children.

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Linda Romano has been a practitioner in the humanitarian sector since 2006, holding positions in philanthropy and grantmaking. Initially raising funds for a community agency in Chicago serving people with developmental disabilities, she went on to grantmaking at Lions Clubs International, allocating funds to healthcare initiatives across South Asia. She then took on philanthropic roles at Development and Peace—Caritas Canada, an organization focused on emergency relief and social justice, and major donations at Centraide United Way of Greater Montreal and the University of Ottawa. Linda has a Bachelor of Arts from McGill University and a Master of Science in Public Service Management from DePaul University.

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The Future of Logistics and Supply Chain Management: Changing Skill Sets and Smart Career Choices

Rico Merkert and Kai Hoberg

1 Introduction

When looking at the future of an industry trying to provide guidance on graduate qualities, changing skill sets, and smart career choices, it is necessary to also look at its past. "The line between disorder and order lies in logistics..." is a quote by Chinese philosopher and general Sun Tzu which he used some 2500 years ago to emphasize that logistics is a key factor in winning wars. Well, many believe that our planet and global supply chains are currently or soon will be battling major issues not too dissimilar to wars. For example, when Mann (2021) uses another famous quote of Tzu saying, "If you know the enemy and know yourself, you need not fear the result of a hundred battles.", he does so the context of the war on climate change. Knowing what is going to be out there in the next decade and preparing yourself (practitioners and students) for what this future holds is something we aim to contribute to with this chapter and book. And while we think the future is bright, and climate change appears to be the elephant in the room, there will be many more battles confronting the logistics and supply chain management (L&SCM) sector. In the last two years alone, firms have been exposed to the COVID-19 pandemic disrupting the industry in both negative and positive ways, online hackers have breached IT security and paralyzed global companies, and with them, entire supply chains. In addition, geopolitical tensions such as the Ukraine war or the rise of China are now driving sureshoring of supply chain elements that are of national interest and deemed essential. Supply for commodities and energy that has been

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believed to be secure is becoming unstable and prices are under severe pressure given inflationary pressure unseen in decades. And then, there are innovations and technological advancements that enable change but also require vision, agility, and strategic investments (not just in tech but also in talent) to manage the resulting need for digital transformation and adaptation to changing environments. All this means that individuals seeking a career in this industry need to be aware of the opportunities and challenges that the future of logistics and supply chain holds in order to be prepared, to adapt and to make smart career choices.

That said, Tzu's wise words on the importance of logistics were lost in many businesses for a long period of time: Logistics was considered a necessary evil, required to carry goods from origin to destination, typically at the lowest cost possible. Accordingly, it was not considered as the function in businesses that was attracting the best talents, and neither was it promising enhancements in individuals' reputation or career opportunities within firms. Way too often, it was seen as not visionary or strategic at all but rather as a lot of operational work geared toward solving problems—yet often involving firefighting with heroic effort that enabled top management to keep the business afloat.

However, across most industries, the term logistics has evolved over the last decade as its focus has been typically extended to supply chain management (SCM).[1] Today, SCM with the aspiration to manage and orchestrate material, information, and financial flows across transnational networks of suppliers and customers is typically seen as a key success factor in many firms. Companies compete for the best supply chain setups and get awarded for their innovative solutions. Increasingly, advanced supply chain management capabilities as evidenced by firms such as Apple, Amazon, Cisco, or Procter & Gamble have been shown to enable outperformance of peers through supply chains that achieve cost advantages, better service or product quality and faster innovation. It has been widely established that firms with superior supply chain competencies can benefit in terms of both customer satisfaction and shareholder value (Ellinger et al., 2012). Accordingly, firms' rankings in business awards, such as the annual Gartner top-25 supply chain list (Gartner, 2022), are carefully observed and celebrated. In parallel, the presence of Chief Supply Chain Officers (CSCO) at board and c-suite level has increased over time ensuring the required executive support to better position and negotiate the complex topics around SCM in firms (Hoberg et al., 2015). In addition, other top managers—including the CEO—have increasingly gained SCM experience in former positions (Wagner & Kemmerling, 2014; Bloomberg, 2021). As a consequence, logistics and SCM are today perceived as a topic and business function with high strategic relevance.

At the same time, logistics and SCM have also come a long way in terms of innovation and technological advancements. The advent of containers was the first technological game changer in logistics in the twentieth century that enabled cheap mass transportation across continents and paved the path toward globalization (see Levinson, 2016, 2021 for the impact of "the box"), and many more innovations have

[1] See four perspectives on logistics and supply chain management in Larson and Halldorsson (2004).

transformed global supply chains since then. Today, logistics and supply chain managers use the latest disruptive Supply Chain 4.0 technologies that leverage big data, advanced robotics, or Internet of things (IoT) sensors to optimize the orchestration of the different physical, financial, and information flows. For example, online retailer Zalando is using weather forecasts to anticipate customer orders and schedule warehouse workers to avoid lengthy delays in order fulfillment (Steinker et al., 2017). Amazon is leveraging Kiva robots in warehouses to minimize the pickers' walking distances and has long been experimenting with automated picking solutions. IoT sensors offered by startups such as Tive or Trackster Global, allow tracking locations of parcels or temperature-sensitive goods and record the unauthorized opening of containers by measuring the incidence of light. These innovative digital technologies can help companies boost sales, cut transportation and warehousing costs and allow for further significant inventory reductions. However, in most companies mastering and implementing these technologies will still require time, talent, and investment. Integrating data, technology, and advanced decision making across many partners is certainly a challenge but also a welcome opportunity for many years to come.

While we are super bullish about career opportunities in logistics and supply chain management in the 2020s, this decade started with an unprecedented challenge for many companies: The COVID-19 pandemic has not only disrupted economies all over the world but also heavily affected many supply chains. The pandemic triggered unprecedented demand and supply shocks and amplified volatility across many industries. Initially, many industries were hit by lockdowns—first in China and later across the globe—which forced many manufacturers to shut down their operations. Soon after, end consumers started panic buying and emptying shelves in supermarkets for goods like toilet paper, canned food, pasta, or painkillers (Alicke & Hoberg, 2020). In 2021, many companies observed the consequences of the massively increased volatility, as car manufacturers were not able to source sufficient semiconductors and had to idle assembly plants (Ewing, 2021) or long lines of container ships were queuing outside major ports triggering huge delays for domestic customers (Financial Times, 2021) or retailers running low on pallets due to lumber shortages and price hikes. Consequently, logistics and SCM have triggered global public interest never observed before. Importantly, firms that prepared their supply chains well with advanced strategies, superior processes, and enhanced visibility were those that outperformed their peers while maneuvering through the storm.

As a result, it is not only our latest research findings and employment data coming out of the industry but also the compounding expert evidence presented in the chapters of this book that let us confidently predict logistics and supply chain management to be a smart career choice for the next generation. As Bloomberg (2021) has put it nicely, "the twenty-first century should be about supply chains." To feel the pulse of this generation, over the period of two years, we engaged with the students in our programs—both at Kuehne Logistics University (KLU) in Germany and at the University of Sydney Business School in Australia to reveal what they think about the future of the industry that they have devoted their studies to. In fact, a key motivation for writing this chapter and for putting the effort into recruiting

27 globally recognized academics in their respective L&SCM fields as well as a senior manager in each of those fields, was some of our students asking during our lectures whether we think that this industry has a future at all? Clearly, those students were concerned about the return on investment of their tuition fees and time in studying a L&SCM degree. Perhaps more importantly, it became apparent that they also wanted to get confirmation or at least more information around the value of preparing themselves for a career in this industry. The following selection of key question from students over last two years indicates that they see potential but also risks associated with a career in supply chain management:

- As automation is revolutionizing supply chains across the globe—with places such as warehouses now being fully automated, what skills do I need to acquire to be able to compete and/or collaborate with the robots and/or drones?
- The advancement of 3D printing has the potential to disrupt many industries—will there be less of a need for cargo shipments and hence less jobs in logistics if goods can be produced locally?
- With shortening supply chains due to political tensions and environmental concerns, will there be less career opportunities in global logistics?
- New machine learning and artificial intelligence approaches are rapidly increasing the maturity of supply chain planning—is there any scope for further improvement? What is the next big thing if planning becomes fully automated and "lights-out," and does this mean the "Death of SC Management" as indicated by (Lyall et al., 2018)?
- Many supply chain jobs are offshored to service centers in other countries, partially to enable tax-efficient supply chain setups—what is the impact on jobs and roles in supply chain management and how does this affect collaboration and leadership?
- With a strong focus on logistics or supply chain management, you can become an specialist but might lose important general skills. Can you still make it into top management?

It is clear that adaptation will have to happen and that skill sets will change. However, the following selection of questions from our students points to a substantial need for logistics and supply chain talent in the future:

- Supply chains need to become more resilient—will machines alone be able to avoid stockouts of essential goods and to save human lives but also to avoid profit disruption for those companies involved?
- Climate change must be addressed to save the planet—how can we contribute to that with smart thinking and better SCM and logistics approaches, e.g., route optimization, collaboration, or better planning?
- Supply chains need to overcome social challenges—currently many supply chains exploit child labor or use commodities from rogue countries. Is there anything that I can do to change those management practices?

- Supply chains need to prepare for the new realities of geopolitical conflicts, constrained commodity supplies and rising prices. How can companies adopt their supply chains to this new volatility and align their shoring decisions (e.g. nearshoring, friendshoring, reshoring), partner relationships and contract types?
- Technology and data enable smarter choices and new business models, e.g., by increasing visibility on supply chain partners, it allows businesses to directly interact with end customers or customize services to the actual needs. Is that not a huge opportunity for startups and a career in that industry more generally?
- Many repetitive and boring tasks can be automated based on smart technologies. Does that not mean no more endless standard planning, routing, or customs declaration activities, but rather creating new roles to advance processes and make them more efficient, which could be quite career rewarding?
- There is still a significant skills shortage for logistics and supply chain talents (McKinnon et al., 2017) which was amplified since the onset of the COVID-19 pandemic. Therefore, aren't supply chain graduates and experts more sought after and could the L&SCM manager be the new sexiest job of the decade?

While each of these questions is fascinating in their own right, in sum we see many more pros than cons for a career choice in logistics and supply chain management. This chapter aims to summarize the key points and also how this book looks at all these aspects in greater detail.

2 Global Trends

All in all, we have been seeing highly efficient and well-orchestrated flows in many supply chains that maximize the value for the parties involved. However, in addition to opportunities, we also see current challenges such as disruption and rising costs in supply chains and emerging challenges that need to be addressed in the next wave of optimization. In line with other research (Utomo et al., 2020), in this section, we focus on four key trends that will affect logistics and supply chain management in the 2020 decade (Fig. 1).

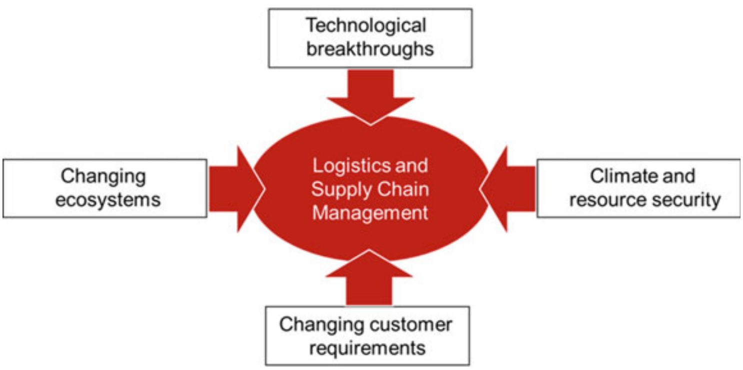

Fig. 1 Key trends affecting logistics and supply chain management in the 2020 decade

2.1 Technological Breakthroughs

With the immense increases in computing power, the availability of cheap sensor technology, and the advancements in Internet communication, there are many technological breakthroughs that affect our everyday lives: We are getting used to new tools such as voice-enabled smart assistants like Amazon Alexa, Netflix recommendations for new streaming shows, or driver support systems in cars such as Tesla's autopilot. While many of these technologies are aimed at the end consumer, many more technologies do provide benefits in a logistics and supply chain management context. We are seeing new warehouse technologies deployed that fundamentally change the traditional man-to-goods design principles, truck routes can be optimized in real time based on traffic conditions, and latest pick-up and delivery requests and data on orders and invoices are exchanged contactless between supply chain partners, thus avoiding new lengthy and error-prone data entry. Using blockchain technology in those processes will add additional value to the process in the form of authentication and verification. However, this is only the very tip of the iceberg and is what is possible today rather than what we may see emerging in the not-so-distant future.

Many new supply chain 4.0 technologies are currently piloted and tested and those will enable a whole new level of optimization. Table 1 provides an overview of ten technology clusters that will more fundamentally affect supply chains in this decade. They promise to collectively substantially increase the efficiency, resilience, agility, and customer orientation of many supply chain processes. Some of these technologies are already relatively mature and have the potential for widespread adoption in the near future (e.g., advanced robotics in warehousing, IoT/smart sensor technology, or core SC analytics), while others need certainly more time for validation and testing (e.g., autonomous transport and delivery technologies or collaboration and crowd platforms). While technology is not the silver bullet to all problems, if many technologies come together, they can enable significant productivity boosts and innovative disruptions, such as the idea of the physical Internet or the promise of lights-out warehouses. While technology appears to be net-advantageous to future supply chains, it is worth mentioning that Internet security and a potential loss of human capabilities/experience could be potential risk factors in the transition process to a more autonomous and smart logistics and supply chain future.

2.2 Climate and Resource Security

In the past years, there has been a notable increase in public awareness about the consequences of climate change and the scarcity of resources. Climate change has been driven throughout the twentieth century due to industrialization and emissions, in particular carbon dioxide that create a greenhouse effect. The twenty-fist century saw a considerable acceleration of greenhouse gas emission. As a consequence, nations across the globe collectively agreed to limit global warming to 1.5 °C under the 2015 Paris Agreement . This effort requires a significant reduction of carbon

Table 1 Overview of Supply Chain 4.0 technology clusters

	Supply Chain 4.0 cluster	Description
1	**Advanced robotics in warehousing**	Robotic systems that allow for improvements in warehouses by increasing efficiency and reducing labor
2	**Autonomous transport and delivery**	Solutions allowing semi- and fully autonomous transportation, ranging from long-distance heavy cargo to short-distance delivery of individual goods
3	**Virtual and augmented reality applications**	Support of repetitive and systematic human tasks through virtual reality applications
4	**IoT/smart sensor applications**	Real-time control of machine and environmental conditions due to analysis of sensor data
5	**Core SC analytics technologies**	Standard tool set of big data and machine learning techniques providing support for SC decision making
6	**Analytics for end-to-end SC planning**	Big data and machine learning techniques focusing on automated end-to-end supply chain planning in real time
7	**Analytics for transport and warehousing**	Big data and machine learning techniques focusing on optimization of transport and warehouse processes
8	**Process automation**	Automation of labor-intensive SC processes driven by robotic process automation and other advanced analytics collecting required data via process mining
9	**Collaboration and crowd platforms**	Connecting consumers of SC activities through the cloud in order to optimize individual transportation and warehousing capacities
10	**Blockchain**	Distributed databases that record transactions in an immutable ledger to enable transparency and value-add services such as smart contracts

Source: adopted from Alicke et al., 2018

emissions by 2030 and achieving near-zero emissions by 2050. While logistics and transportation are directly only responsible for around one-fifth of global CO_2 emissions, manufacturing and shipping all types of products fall clearly into the scope of supply chain management. Companies and governments have recognized that CO_2 emissions can be reduced by superior supply chain management practices.

On a global level, the planetary boundaries are a limiting factor for economic growth: For many commodities and raw materials, humankind is consuming resources at a staggering speed that is exhausting the planet. On a firm level, it becomes much more difficult to acquire the required raw materials at reasonable prices and at steady rates, not to mention the race of China and other countries to secure future rights for most of the key commodities they need for their growth. In the past years, rare earth metals have been the most pressing case of such supply constraints (Rauer & Kaufmann, 2015), but with the increase in demand for electric vehicles, other metals such as lithium or cobalt are now on the radar of governments and investors too. As such, it is likely that in the future ensuring access to raw materials will become a much more widespread challenge.

The implications for SCM and logistics are becoming clearer every day: Managers need to review their transportation and manufacturing networks much more frequently to deal with higher energy costs, local environmental requirements, and possibly the limited availability of important resources. Companies need to form new alliances and find partners that help them collaboratively reduce greenhouse gas emissions. This is particularly important as scope 3 emissions are increasingly becoming the gold standard for measuring emissions and those also include all indirect emissions that occur in a company's value chain. New technologies need to be reviewed and tested that can reduce a company's footprint—technologies that could become game changers or entirely fail despite huge investments. And ultimately, trade-offs need to be reviewed and defined once it comes to agility and responsiveness on the one hand and environmental responsibility on the one hand. Accordingly, it will become a much more complex question if Apple should continue to ship "empty iPad boxes halfway across the world and back" (Lovejoy, 2021) to avoid unhappy customers. While under the current economics, this might be feasible the decision could change with a much stronger focus on greenhouse gas emissions and different ethical guidance.

2.3 Changing Customer Requirements

Customer centricity, i.e., delivery products in line with customer expectation, has always been the overarching objective of logistics and supply chain management practices: getting the right product at the right time to the right location at the right price. However, the complexity of all these activities has grown exponentially since the days when Henry Ford declared to offer the Ford Model T in "any color so long as it is black." Today, customers of most product categories expect a myriad of options or straight customization which increases the complexity in design, sourcing, and manufacturing. And customers are now used to getting the ordered product the next day, if not the same day and if possible within an hour time frame in the last mile delivery context (Merkert et al., 2023). This challenge drives the complexity and efforts in warehousing and transportation for many retailers and logistics service providers alike. Due to this so-called Amazon effect, customers are accustomed to a world where individual needs are met with one-click ordering, fast delivery, and instant gratification (Forbes, 2020). This also affects B2B customers who are getting used to these extraordinary customer services from their private lives (as the new normal). In future, this may well lead to hyper-expectations everywhere and companies in fierce competition are often not able to charge for the value add of these costly expectations. As a result of supply chain operations and their models becoming more complex, the (B2B) customers need to be segmented (Protopappa-Sieke and Thonemann 2017) to avoid being overwhelmed by the many differing operational requirements and demands. As observed during the COVID-19-related lockdowns, markets can quickly shift with customers now engaging much more with e-commerce platforms. Companies that can adjust their supply chains quickly in periods like this increase their market shares, while others suffer. In addition, an agile supply chain also supports entirely new business models that are very customer-centric. For example, ultra-fast textile retailers such as Shein or Fashion Nova launch up to 1000 new styles per week and benefit from regional supply chains that can react to the latest Instagram trends. In this way, the time from design and prototype to production and sales is reduced by up to three days. Accordingly, these firms can offer an agility and resulting resilience many established retailers with much longer planning cycles can only dream of.

2.4 Changing Ecosystems

With advancements in technology, changes to operational environments and evolving consumer preferences, logistics, and supply chain management ecosystems have not only become a more competitive landscape but have also transformed into advanced industries. Central to this book, we argue with Boiarynova and Kopishynska (2021) that young and creative people inject their non-standard solutions into logistics and supply chain companies. New market entrants and new business models are challenging the market leaders (e.g., Wagner and Kurpjuweit, 2023, Chapter "Startups in the Logistics Sector: Value Propositions and Potential Impact" of this book), many of which have grown to become global companies in their own right (in the Australian context; see, for example, WiseTech Global or in the European context, Forto) with significant market and bargaining power.

In addition, increasing market concentration (which has continued to play out during the COVID-19 pandemic), there have also been trends toward omni-channel distribution, a boom in e-commerce, horizontal and vertical collaborations (e.g., joint ventures), as well as a shift from globalization to onshoring and sure shoring. As such, we argue that it is not only companies but logistics ecosystems that have been transformed by disruptive technology transition (e.g., Mikl et al., 2021) and an increased focus on environmental sustainability, for example, through platforms that create value through value co-creation, co-opetition, and dynamic configuration (Lin et al., 2021) and that have also been shaped by political environments including competitive regulation and tax regimes. While those ecosystems are increasingly centered around automated warehouses and distribution centers, it is also the last mile that continues to experience substantial change with delivery drones (Merkert & Bushell, 2020) and automated, electric vehicles (Monios & Bergqvist, 2020) taking over from traditional transportation assets. And, of course, those changes extend into more traditional supply chain areas including procurement or risk management in a circular economy. We argue that the COVID-19 pandemic has accelerated some of those changes and has exposed the need for resilient and agile global supply chains as well as empathy at the individual level. Many supply chains were and are severely impacted since the onset of the pandemic but not everything about that is problematic, as so often in the context of innovation and market forces. While air cargo has been traditionally loss making (Merkert et al., 2017), the COVID-19 pandemic and subsequent global supply chain disruptions have turned air cargo logistics into profitable and commercially viable activities and on the dawn of a golden decade for that industry (Merkert, 2023, Chapter "Air Cargo Logistics: The Dawning of a Golden Decade?" of this book), which has started and will continue to create career opportunities in this space. We would like to think that those opportunities go far beyond air cargo extending to all parts of logistics and supply chain management.

3 Implications for Supply Chain Talents

After the record year of 2021, which has proven how critical global logistics are to the performance of almost any commercial industry and even entire economies, we predict the logistics and supply chain sector to continue to grow significantly. As such, it is unsurprising that globally both private and public sectors are currently expecting skill shortages in logistics and supply chain management in the future. In the Australian context that translates into predicted job growth in logistics of 7% in 2022 alone with 60% of logistics employers indicating that they will increase salaries again for the 2021/22 financial year (Hays, 2021). It is, therefore, argued that there has never been a better time to enter the logistics and supply chain management industry and build knowledge and skills for a career in this sector.

However, the current generation of supply chain talents we see in our classrooms at both KLU and the University of Sydney Business School is very different from early logistics and supply chain managers that started their careers ten to twenty years ago. In contrast to their predecessors who were often autodidacts or received their first relevant training on the job, the new generation benefits from comprehensive training programs and formal education. As such, much of the current talent pool will hold bachelor and master degrees in relevant fields or have had access to professional training courses and certificate programs. As a result, they are able to understand and apply the latest tools and technologies and—perhaps even more important—take a cross-functional end-to-end perspective on many supply chain-related processes to address challenges across silos.

This siloed perspective has been a severe challenge for supply chain managers for a long time: functions aimed to optimize themselves without considering the effects on other functions and overall firm profitability (Hoberg et al., 2015). For example, logistics departments have often minimized transportation costs by booking slow and unreliable carriers, while sourcing/procurement departments have unisono identified the cheapest suppliers possible by not considering any volume flexibility and manufacturing minimized unit production cost by increasing production batch sizes for fixed cost degression. Having instead a cross-functional perspective to achieve the best possible outcome for the company is something where today's and future graduates can add value. To align all these perspectives has become an important task for supply chain managers in the past few years and will remain a key skill in the future.

What that tells us is that supply chain talents will be required in a large variety of industries and not only in the logistics sector. Naturally, the manufacturing and retail sectors offer very attractive entry and career opportunities for supply chain professionals. Importantly, supply chain talents with the required analytical, cross-functional, and communication skills are now also highly sought after in other sectors such as consulting and banking. Nevertheless, the areas of logistics versus supply chain management specialization do differ and will become more important in the future as we outline in the next section.

3.1 Different Job Profiles

A very important aspect when identifying the graduate qualities and required skills for logisticians and supply chain managers is the very heterogeneous landscape of job profiles in this industry. As such, we usually advise our graduates to decide to what extent they would like to become specialists or generalists. For example, do they want to take an end-to-end perspective on supply chain process improvement or do they prefer to focus on applying in-depth expertise and improving optimization tasks like demand forecasting, production planning, or truck routing. Based on this intended focus, the skills requirements differ markedly. While specialized knowledge will become more important as complexity increases in the future, so will generalized knowledge such as finance or consumer research.

Figure 2 illustrates how a future digital supply chain organization could look. Many very specialized roles will be created—for example, a predictive demand management unit that might evolve from the current demand planning teams. The demand management unit of the future will have professionals with a very qualitative skill set on the one hand and professionals requiring state-of-the-art data science expertise on the other hand. As market experts align with the sales team, they need to understand processes in both functions, must be able to communicate with the sales team, and must judge the impact of promotions or the timing and effect of new product introductions. Market experts need to have commercial expertise and are highly skilled in applying market intelligence and understanding competitor

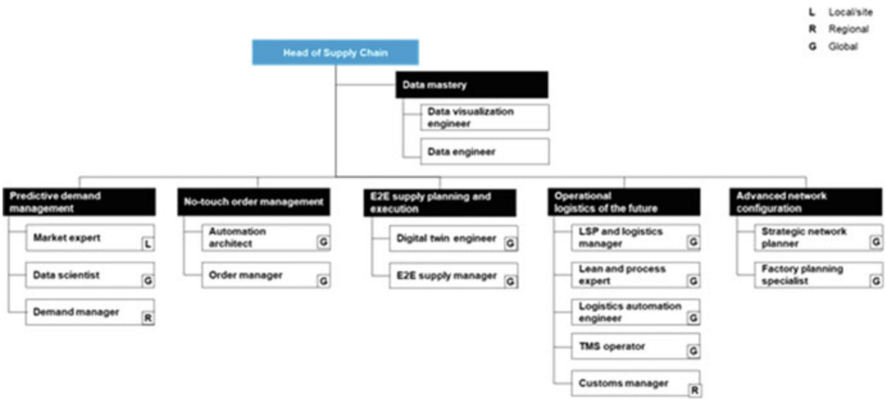

Fig. 2 Outlook at future digital supply chain organization. Source: adapted from Alicke et al. 2022

dynamics (Alicke et al., 2022). On the other end of the spectrum, the demand planning data scientists use all types of data inputs to build machine learning and AI models that enable them to accurately forecast sales. Skills for data scientists in demand planning build on training and expertise in statistics, machine learning, and languages such as Python or SQL. Demand managers again have a different role as they manage exceptions and provide human input if the systems do not perform sufficiently or are disrupted (in crisis). Skills are most similar to the historical demand planner role that mixes different commercial and supply chain knowledge as well as problem-solving and communication skills. As illustrated in this simplified example, there will be a role for every talent but the required skills will ultimately be very different in the future. For some roles, a more cross-functional career might be helpful, while for others a very focused approach seems to be more effective. Likewise, education and training to get there will differ very much and should remain open-minded and as flexible as possible.

3.2 For Students: Learn to Learn

In the midst of the pandemic, Forbes published a lead article entitled “Forget Finance. Supply-Chain Management Is the Pandemic Era’s Must-Have MBA Degree,” which highlights the notable shift in the public perception of university degree programs: Studying logistics and SCM is now considered something very valuable that prepares talents for a successful and financially attractive career. This does apply not only to MBAs but also to master and bachelor students. Supply chain talent is in high demand, and related expertise is seen as a potential success factor for both gaining employment and making it to the top. In addition, in contrast to 20 years ago, students today have the advantage of having access to many specialized degree programs that prepare them for a career in logistics and supply chain. We can speak with authority about such programs being offered at the University of Sydney Business School and Kühne Logistics University and are aware of many other interesting degree opportunities around the globe that have been started in the past years. However, while students need to be aware of the choices they make at the beginning of their career, it does not stop there as key skills now not only include empathy but also agility, which involves continuous learning and adapting to constantly changing environments.

We argue that students need to unlearn some old habits and to learn how to constantly adapt to change (resilience) and to strive further (performance). As such, university education is only partly about teaching theoretical knowledge and providing insights into the latest logistics and supply chain management issues such as understanding the different incoterms, learning the latest EDI standards for data exchange or getting familiar with standard ERP planning software packages. Such knowledge is nice to have (and useful in a job interview) but not only is this knowledge outdated relatively quickly with today’s accelerated technical change, it is also easily accessible online and can often be learned on the job in practice. To us, a successful logistics/supply chain program, therefore, blends different aspects of

	Kühne Logistics University (2 years)	The University of Sydney Business School, ITLS (1.5 years)
Core units	Business Analytics & Econometrics	Production and Operations Management
	Business Logistics & Supply Chain Management	Introductory Supply Chain Analysis
	Leadership & Organizational Behavior	Supply Chain Planning and Design
	Strategic Issues in Supply Chain Management	Logistics and Supply Chain Management Systems
	Transportation & Distribution	Global Distribution Strategy
	Warehousing & Intralogistics	Sustainable Logistics and Procurement
	Managing Supply Chain Complexity	Capstone project
	Supply Chain Analytics	
	Applied Research Methods	
	Capstone project	
Elective units	Analytical Methods in Logistics & Supply Chain Management	Managing Supply Chain Disruption
	International Economics	Logistics and Future Cities
	Corporate Social Responsibility	Spatial Analytics
	Sourcing and Procurement Management	Maritime Management and Logistics
	Sustainable Logistics	Aviation Management and Logistics
	Sustainable New Product Development	Environmental Footprints and IO Analysis
	Humanitarian Logistics	Life Cycle Analysis
	Marketing Analytics	Introduction to Dashboarding and Data Visualisation
	Maritime Logistics	Industry Placement
	Sustainable Finance	Industry Self-Sourced Placement
	Data Science	Leadership and Collaboration Study Tour
	Economics of Digital Transformation	
	Logistics Information Systems	
	Revenue Management and Service Operations	
	Independent Studies: Academic Project	
	Independent Studies: Entrepreneurial Project	
	Electronic Business	
	Sustainable Globalization	

Fig. 3 Curriculum comparison MSc in logistics and supply chain management (2022). Source: Kühne Logistics University and the University of Sydney Business School

management education by teaching graduates critical problem-solving and analytical skills as well as providing deep insights into relevant core concepts of logistics and supply chain management.

Figure 3 compares exemplary the 2022 curriculum of the MScs in logistics and supply chain management at KLU and the University of Sydney Business School. Typical for such degrees, students get exposed to a number of core units and can choose electives according to their interests. A focus lies on logistics and supply chain specific aspects that are more about concepts and methodologies and provide fundamental insights into the key drivers of logistics and supply chain management: How can you use Little's Law to estimate lead times and throughput? What are elements affecting safety inventory needs in warehouses? What are the factors that stimulate a supply chain partner to accept your contract? How to design and operate sustainable supply chains? Based on these fundamental concepts, students are expected to be able to adopt not just the learned knowledge but more importantly taught skills in the future and learn how to resiliently deal with new challenges, changing environments and new software tools.

In addition, great L&SCM programs should further help participants to unlearn bad habits and to instead learn and practice the DNA and mechanics of tools that can be applied in the future. If we take the inventory management context example, it is common practice to define fixed targets for the inventory coverage—Let us define a safety stock to ensure we cover 10 days of average demand for all products.

Participants should learn that they must consider the volatility of demand rather than only average demand. For certain products with stable demand, 5 days might be sufficient, while for others 50 days are much more appropriate. And they should segment products based on the service level needs. For certain products, it might be sufficient to have 90% service levels (or move to make to order), while for other more critical products, a 99% service level is barely tolerable. The key message here to our students is as follows: Move away from one size fits all to more differentiated approaches.

3.3 For Professionals: Life-Long Learning

Many different education providers have identified professionals as the target audience for their activities. Certainly, life-long learning is here to stay and likely to further grow in the future as knowledge is getting out of date more quickly and talents need to become familiar more regularly with new trends and approaches during all stages of their career. Professionals working in logistics and supply chain management now have access to many sources for their learning experience: universities, professional bodies, specialized online services, and much more. And still many SC executives have capacity for improvement of their L&SCM foundational knowledge, as many have moved into supply chain positions from other functions (Hoberg et al., 2014; Flöthmann & Hoberg, 2017).

Many universities offer MBAs or specific executive education programs for managers that combine theory with practice in the field. While the MBA is typically more geared toward helping future managers to develop their managerial, strategy, and leadership skills and to train their ability to analyze and solve complex business challenges, more specialized executive education programs often provide detailed insights into specific hot topics. For example, they learn about all the different aspects related to sustainability in logistics, understand the foundations of leveraging data in supply chain management, or become familiar with the latest technology trends affecting their work environments.

Over the last decade, many professional organizations, such as trade associations, supporting logistics, and supply chain professionals, have emerged across the world. To just name a few major associations, Council of Supply Chain Management Professionals (CSCMP) based in the US, the German Logistics Association Bundesvereinigung Logistik (BVL) that is the largest professional body in Europe, the British Chartered Institute of Logistics and Transport (CILT) with many overseas sections (including Australia) and the US Association for Supply Chain Management (APICS) that is offering many certification programs. All bodies have different activities that provide their members with access to training programs. Their large networks enable professionals to identify the right points of contact for helping to solve very specific situations and also to kick-start career moves.

In addition to these established players in the professional education market, new opportunities are going to arise with the growing availability of online services. For example, MIT has launched the massive open online platform (MOOC) EDx that is offering a variety of rather popular supply chain courses that can essentially be completed at no cost for the user unless obtaining a certificate (which of course, most participants will do). Corporate players in the industry, such as Amazon or WiseTech Global, increasingly also offer their own continuing professional education services. Further, the number of Webinars and Web conferences has—in particular during the COVID-19 pandemic—grown exponentially. Importantly, the quality of the aforementioned offerings varies with content ranging from short sale pitches to very sophisticated and detailed in-depth presentations and discussions. Therefore, it typically takes time to understand what to focus on and also to involve a university. Another medium is podcasts that are easy to digest when no screen is available to stay up-to-date with recent trends and developments. There is a growing portfolio of frequently updated logistics and supply chain-related podcasts such as "Leaders in Supply Chain" hosted by Alcott Global or "Digital Supply Chain" hosted by SAP.

Ultimately, every professional needs to decide what works best for them to stay up-to-date along the life-long learning journey. Fortunately, for the L&SCM sector, there is a growing service offering in this space, which provides opportunity for each and every supply chain talent, and we believe that a successful career will be dependent on leveraging these from a very early stage and all the way through to the top.

4 Synthesis of This Book and Future Skill Requirements in the Various L&SCM Areas

While this introduction chapter has provided a general overview of what skill sets will be required for a successful career in supply chain and logistics, the remaining chapters provide more in-depth insights into key capabilities for success in the main functional logistics and supply chain areas and industries both from an academic and practitioner perspective (written by globally recognized experts and senior managers in each area). This section provides a brief summary and synthesis of those skills based on the key findings and supply chain trends presented in each chapter in italics.

Gattorna and Ellis (2023) detail in Chapter "The Impact on Supply Chain Networks of Shifting Demand and Supply Dynamics" how demand and supply shifts (e.g., globalization and more recently COVID-19) have had lasting impacts on global supply chain networks. As such, they identify *creativity*, *flexibility,* and *hard-core analytics* as paramount supply chain skills that will enable future leaders in this space to adapt to the increased volatility and risks that firms operating in those networks are exposed to.

Boute and Udenio (2023) show in Chapter "AI in Logistics and Supply Chain Management" that despite the widespread availability of data, combined with sustained improvements in computing power, artificial intelligence and machine learning still have limitations and come with risks in regards to supply chain decision making which creates fascinating opportunities for human involvement, especially for tech-savvy and data-literate graduates.

Building on this, Hoberg and Imdahl (2023) detail in Chapter "How to Design Human-Machine Interaction in Next-Generation Supply Chain Planning" how to best design human–machine interaction in next-generation supply chain planning. Importantly, they argue that such interaction will require, on the human side, in addition to extensive *cross-functional expertise* and *analytical skills,* a key ability to conduct *end-to-end thinking*.

We discussed climate change and future resource scarcity as a mega trend in Sect. 2 of this chapter. In our view, the question of how to become greener is really the elephant in the room of supply chain management. As part of that discussion, Sarkis (2023) uses Chapter "The Circular Economy and Green Supply Chains" to identify managerial skills and capabilities that will enable firms to green supply chains which play an important role in the instigation of the circular economy. In his view, future, managers will most importantly need e*xpertise in sustainability concepts*, an ability to *communicate across functional silos* and a deep *understanding of emergent technologies* to implement both concepts, green supply chains and the circular economy.

With a focus on logistics, McKinnon (2023) then discusses in Chapter "Preparing Logistics for the Low Carbon Economy" the nature and scale of the climate change challenge (i.e., net-zero commitments) facing businesses and examines what this means for the future of the sector. His discussion on the capabilities that managers will have to acquire or strengthen to prepare logistics for a "net-zero" future reveals skill requirement around an *understanding of emission-generating processes* within logistics systems and across supply chains, the *determining of the most timely and cost-effective means of decarbonizing logistical activities,* as well as the *planning, implementing, and co-ordinating of a broad range of carbon-reducing actions*.

We then zoom into functional areas and important parts of global supply chains. Starting with an outline of the future of this party logistics providers (3PLs), Wallenburg and Knemeyer (2023) discuss in Chapter "The Future of 3PLs" how the operating environment of 3PLs is getting increasingly VUCA (volatile, uncertain, complex, and ambiguous) which influences not only the 3PLs but also their clients' success and their associated demand for logistics services. As such, they identify *enhanced leadership and management skills* as key success skills in the context of a predicted increasing *need for collaboration and value co-creation* activities with clients. In that sense, the ability to establish credibility with the individual client, the ability of supply chain choreography, and the ability to think and act consumer-centric are shown to be key success factors for a future career in the 3PL sector.

As a key partner and sometimes competitor of 3PLs, the air cargo logistics sector is then introduced by Merkert (2023) in Chap. "Air Cargo Logistics: The Dawning of a Golden Decade?". As COVID-19 and the boom in e-commerce have resulted in record high yields and profit margins in this traditionally rather low margin and volatility sector, air cargo is now being taken more seriously (as the backbone of many global supply chains). More importantly, the recent developments (which may be the beginning of a golden era for the sector) have also created opportunities for the sector to set itself up for the new normal future, including new business models as well as horizontal and vertical supply chain integration. Activities around fleet renewal and reinvestment of the unprecedented cash flows into digitization and transformation of air cargo firms are shown to shape a future of fascinating career opportunities albeit one where *interpersonal skills, data literacy, and agility* will matter even more than today.

Similar to air cargo, the maritime logistic sector is currently experiencing record profitability (and therefore immense opportunities for transition and transformation) but also frequent and substantial disruptions. In that context, Hussein and Song (2023) show in Chapter "Maritime Logistics for the Next Decade: Challenges, Opportunities and Required Skills" that management of global shipping lines will in the future require *critical thinking, innovative, and technological competencies* in order to align with the digitalization and automation epoch in the maritime logistic industry.

As demand for door-to-door shipments is growing in unison with the e-commerce boom, last mile delivery, be it aerial drones (e.g., Merkert & Bushell, 2020) or surface transport city logistics solutions, is becoming increasingly popular and relevant in the global supply chain context. As such, Bell (2023) introduces in Chapter "Future Directions in City Logistics" what he sees as future direction for city logistics in light of liveability and sustainability (e.g., zero emission first and last mile vehicles) of cities. In addition to the evolution of omni-channel retail, the pandemic and the climate emergency have accelerated the change in that sector, aided by technological advancements. However, he also argues that proliferation of data associated with supply chains is leading to new and larger cyber vulnerabilities and hence future key skills include not only being a *team player* but also *computer literacy* and *operational knowledge*.

As servitization has been a key trend across most industries, it is crucial to logistics and supply chain management. In that sense, Choi, (2023) reviews in Chapter "Recent Advances of Service Supply Chain Management" the extant service supply chain management (SSCM) literature and provides a research agenda based on the identified gaps and observed industrial practices gaps. He argues that SSCM is critical to global business operations and will require in addition to an *extended knowledge of supply chain management, deep information technology skills, and an understanding of sustainable logistics*.

At the heart of this book is the development of directions for future skills that will enable successful careers in the logistics and supply chain sector. As technology is so important in this industry, Gammelgaard (2023) develops in Chapter "Competence Development, Learning and Change in Supply Chain Management" not only a decision grid that allows combining new technologies with supply chain management (SCM) processes for development of innovative strategies, but also deploys process theory to learning, leadership, and change processes. As a result, she identifies *digitalization, transformation, and managing paradox skills* as key capabilities for required competence development for supply chain management and future success of organizations in the sector.

As a key enabler of innovation and digitalization, startups have become a driving force of change and important players in the logistics and supply chain management sector. What is more, startups are often a springboard for entrepreneurs and attractive employers for young talent. In that context, Wagner and Kurpjuweit (2023) use Chapter "Startups in the Logistics Sector: Value Propositions and Potential Impact" to categorize logistics startups that have emerged on the market and to show how such startups affect incumbent players in the logistics sector as well as value creation. He argues that startups require a different set of skills, most importantly, *entrepreneurial orientation, strategic decision-making skills as well as fundraising and due diligence skills*.

Chapter "Warehousing 2030" then takes a close look at what students (judging from the experience at the University of Sydney and KLU) see as a core element of supply chain management that is currently changing the most, which is the management of warehouses. In his chapter, de Koster (2023) shows why warehousing operations are crucial in any supply chain, as they decouple demand and supply in time, space, and quantity. Similar to the discussion in the preceding chapters, the e-commerce boom has a substantial impact on quantities and data going through warehouses and the increasing level of automation changes the way warehouses are operated which will require both adaptability and analytical skill sets. This chapter further illustrates that securing a *safe, ergonomic, and sustainable work* environment in warehouses remains an important challenge, and as such, *leadership skills* and *teamwork* will be of ever-increasing importance to achieve successful future outcomes in this sector.

The next three chapters discuss changes to key supply chain business functions and what that means to future skill sets. Bode et al. (2023) focus in Chapter "Future of Procurement: Insights from a Global Survey" is the future of public and private procurement and provides insights from a global procurement executive survey. Based on this, they develop a framework for providing an outlook on the procurement of the next decade which, in their view, will be exposed to even more disruptions but also recognition in the form of playing a strategic role that drives growth, innovation, and value creation and hence requires skillful orchestration of firms' supplier relationships. As such, they identify negotiation as a key skill for successful careers in procurement in the supply chain management context.

Similar to procurement, supply chain planning has evolved as a key business function in today's global supply chains. In that context, Kraiselburd (2023) illustrates in Chapter "Agility in Supply Chain Planning and Execution" how important agility has become in supply chain planning and execution. He further discusses how the design and implementation of decision systems to detect and respond to "special," uncertain, and non-predictable causes of variation (such as COVID-19) will drive the future success of supply chains. Such systems combined with *analytic, communication, and agility skills* are shown to be a key for detection of supply chain disruption as well as quick and effective decision making.

Building on this theme of disruption, which in the future will be part of risk management considerations of any global supply chain, Thiell and Wilmsmeier (2023) develop in Chapter "Risk Driven Supply Chain Design: Options and Trade-offs in Complex Environments" a framework that allows decision makers to assess strategic supply chain design options and their trade-offs in complex and fragile environments. Similar to Chapter "Agility in Supply Chain Planning and Execution", they identify agility and resilience as key skills but also highlight that capabilities related to managing such complexity, fragility, and risk have the potential to become key factors in future supply chain design and management. Accordingly, supply chain professionals will need to be able to identify and interpret *complexity of risk in supply chains*, which will further require the ability to take a systemic view as well as data analytic skills.

As discussed in Sect. 2 of this chapter, data as the new oil of many industries is clearly going to be shaping future skill sets in logistics and supply chain management. What is more, visibility, transparency, and trust along the supply chain have become important topics in the academic literature and supply chain practice. In that context, Cui and Gaur (2023) discuss in Chapter "Supply Chain Transparency Using Blockchain: Benefits, Challenges, and Examples" benefits, challenges, and examples of using blockchain as a tool for enhancing supply chain transparency. With a focus on improvement of process efficiency, supply chain optimization, and creation of new and innovative use cases, they reveal that a *general understanding of blockchain technology, SQL data manipulation skill, and cloud computing* will be key skill sets of any supply chain manager in the future.

Taking the blockchain in supply chain management idea a step further, Taudes and Rainer (2023) describe in Chapter "The Potential of Blockchain in SCM: PI Meets Blockchain" how blockchain architecture based on ant colony optimization may support the operations of the "physical Internet." They further introduce a blockchain-based decentralized system for PI container that allows autonomous decision making. The future of supply chain management presented in this chapter will accordingly require *skills in distributed ledger technology, an understanding of the physical and the Internet of Things (IoT) and edge computing skills* for supply chain management.

As supply chain disruptions are often accompanied with natural disasters, an area that has dramatically gained in importance is that of humanitarian logistics. Fard and Papier (2023) show in Chapter "Collaboration in Humanitarian Operations in the Context of the COVID-19 Pandemic" how different forms of collaboration can improve humanitarian operations, especially in the context of disruption and events such as the COVID-19 pandemic. In that context, they identify *adaptability and creativity* as key skills along with crisis management and *contingency planning capabilities as well as multilingual skills* as key success factors of future humanitarian logistics managers.

To round off the book, Luke and Walters (2023) present in Chapter "Logistics Challenges and Opportunities in Africa in the 2020s", a view of the future of supply chain management from a developing world perspective. While discussing future logistics challenges and opportunities for the African continent, they remind us that truly global logistics and supply chains are often operating in environments of poverty, poor infrastructure, political instability, and skills shortages. They skillfully

Fig. 4 Synthesis of key skills required for a successful career in L&SCM in the future

tie the discussion back to what has been established in Chapter "The Impact on Supply Chain Networks of Shifting Demand and Supply Dynamics" by highlighting the importance of free trade agreements that could enable Africa and other developing regions to enter an era of "supercharged mobility." Accordingly, critical competencies to achieve this will be a broad range of hard technical skills, particularly in the technology and digital areas, but perhaps even more important also soft skills such as being able to think analytically, across cultural barriers, to communicate, collaborate, and negotiate effectively, and finally to manage change.

To synthesize the key skills identified in the 21 chapters in this book, we have produced the word cloud shown in Fig. 4. Due to the diversity of the logistics and supply chain management field and its functions, there are no dominating key skills. Our synthesis shows that soft skills such as agility will be of similar importance than skills related to data analytics. What appears to be emerging is the need for a better understanding of the complexities of supply chain management including sustainability concerns and opportunities.

In addition to these academic 21 contributions from internationally recognized professors, we have secured senior managers (such as the CEO of DHL Consulting, the Managing Director of Toll Group, the CEO of Jungheinrich or Partners of BCG, and McKinsey & Company to just name a few) from the various parts of the logistics and supply chain management industry to provide us with their perspectives regarding the required skills that will make a career in this sector future proof. While each of the following 20 chapters is accompanied by one management perspective, this overview chapter offers two management perspectives. The first perspective is provided by the CEO of DHL Consulting, and we anticipated that this view will confirm and comprehensively summarize the views of the many practitioners that have contributed to the other chapters. We then have the managing partner of Alcot presenting the view of an internationally leading headhunter on the skill sets required in future leadership positions in logistics and supply chain management. Who would be better suited than a headhunter to comment on those required skill sets? To hear from the horse's mouth what will be required to succeed in this sector is in our view invaluable.

Management Perspective on What Does It Take to Succeed in Tomorrow's Supply Chain and Logistics Industry?

Sabine Mueller
DHL Consulting, Bonn, Germany

Our industry is witnessing a massive transformation. Technologies, such as artificial intelligence, robotics, the Internet of things (IoT), drones, and blockchain, are redefining our business models and workforce. This presents us with a huge opportunity to collect data and use it more effectively. Analytics will empower us to further boost real-time, end-to-end visibility, take decisions in real time to optimize our operations, and enhance forecasting capabilities to eliminate inventory shortages. This transformation drives changes in our workforce and dictates what will be the must-have skills in the years to come.

Digitalization will affect virtually every role in our organization, at least to a certain extent. At Deutsche Post DHL Group, we expect that by 2030, about 70–80 percent of service desk tasks will be handled by chatbots. Approximately, 80 percent of repetitive blue-collar tasks will be performed by robots, and about 70 percent of transactional white-collar tasks will be automated. Overall, we expect that 30 percent of our tasks will be automated by 2030, and as a result, parts of our workforce will have to be re-deployed. Transactional white-collar tasks will be automated first, followed by predictable, physical work. At the same time, analytics will be increasingly deployed across the entire value chain, which will enable us to move from explaining the past to predicting the future. Consequently, in the future, we will need new skills. So which ones are these?

Social, Emotional, and Advanced Cognitive Skills

Some hard skills are more likely to be replaced by technology over time. Soft skills that are less susceptible to automation in the near future, such as communication, collaboration, problem solving, creativity, and emotional and social intelligence, will therefore become even more valuable moving forward.

(continued)

Digital and Technical Skills

Against the backdrop of a changing technological landscape, future supply chain and logistics professionals will need to be open to work with technology and possess a degree of technological literacy. Additionally, new technical expertise will become relevant in such areas as artificial intelligence, cloud computing, autonomous systems, and IoT.

Data Science and Mathematical Skills

As data science is taking center stage amid digitalization and big data, knowledge of math and data analytics will be highly sought after. Being able to tap into the potential of the huge amounts of data we gather and to make sense of it for better decision making will be one of the things that will set us apart in the market. Even at an executive level, having an understanding of data science will become more important.

Digital Security and Data Hygiene

Finally, and related to the same developments, digital security and data hygiene will be priority topics that call for new skillsets too—whether you are a technical expert or not, you need to possess basic skills in these areas.

The workforce transition is inevitable. As leaders, it is our responsibility to proactively drive and role-model the necessary change, by first and foremost, upskilling our existing workforce and facilitating life-long learning, followed by redeployment and acquiring talent with new, difficult-to-train skillsets.

At DHL Consulting, we are doing just that. To stay ahead of the curve and attract the right talent, we made changes at all levels. We have established a data analytics team, and all our employees are being upskilled in data science. Life-long learning has become a central tenet of our approach to people development. We foster a change culture powered by diversity, trust, and an openness to learn from mistakes. Lastly, we took measures to enable flexible work: We became a paperless office with digitalized processes, virtual collaboration tools, and a new, agile office environment.

Digital readiness is, however, an ongoing journey, which requires the commitment to change and innovate from us today as well as from you, as our future leaders. My key takeaway from navigating today’s rapidly changing business environment: Don’t resist change, embrace it!

Management Perspective on the Vital Skills for SCM in the Future from a Headhunter Perspective

Radu Palamariu
Supply Chain and Logistics, Alcott Global, Singapore, Singapore

As we are regularly engaged by our clients to headhunt senior positions across supply chains, we have noticed that very often it comes down to 7 skills: three hard skills, three soft skills plus one fundamental skill. The technical skills may change here and there. And for sure, there are different nuances depending on the exact role which I will not go into below—i.e., a head of manufacturing would require a solid foundation in factory expertise, whereas a head of procurement would need to have vast contract negotiation experience. But the soft skills and the fundamental skill, I would argue, are here to stay for the next many years.

Three Hard Skills

Analytical and Data-Related Skills

Data are the new oil. Amazon and Alibaba know what you are going to buy and what people are going to buy, even before we know that we are going to buy it, because of the **power of the data** and harnessing it. More and more companies, no matter their segments, are going into that. So **it is a crucial hard skill to have now**. Does it mean that all of us will be data scientists? Does it mean that all of us have to be experts in this? No. When I say that the top talent needs to have these skills, I mean that **you need to have some exposure and you need to make sense of data**.

Digital Project Implementation Skills across Different Areas of the Supply Chain

There are a lot Industry 4.0 initiatives being implemented across the board: IoT, robotics, automation, RPA, 3D printing, digital twins, etc., and initiatives that make the different processes in the supply chain faster and easier. Ultimately, the goal of **supply chain digital transformation** is not to create something fancy around blockchain, AI, machine learning. It is to have tangible results inside the company. **The more this type of projects you have under your belt, the more valuable you are to organizations**.

International Exposure and End-to-End Experience

Number three in terms of what makes a top talent is broken into two: **international exposure** and **end-to-end** experience across the different functions of the supply chain. International exposure is, very simply put, working across different geographies, territories, and cultures. If you strive to be in a global position, in a multinational, it is a must that you **have worked**

(continued)

at least on two continents. One of them should be Asia, just because of the sheer size and growth potential. **Exposure** to the different functions: **plan**, **procure**, **make**, **and deliver**. So if you manage to cut across those four somehow or have different exposures to these, it gives you that full end-to-end understanding of what is supply chain. And I think that is extremely valuable."

Three Soft Skills

Presentation and Communication Skills

Can you **catch the attention of an audience**, whether it is the board, whether it is the CEO, whether it is the senior leadership of the team, whether it is your boss, or whether it is your clients, **within 30 seconds**? Can you do that? If you can, that means you have this ability, you have **great presentations skills and great communications skills**. If you do not, you have to work on it.

Influencing Engagement Skills

With different stakeholders in the organization: upwards, sideways, downwards, inside the organization, external world, **how do you present** something and **influence** somebody that you may or you may not have authority over, **to come on your side** and join you on that project? How do you **build partnerships**? How do you **build ecosystems**? How do you build **long term relationships** with both your vendors and as well your clients? Business is about relationships.

Change Enabler

Change is the only constant. **We will forever need to change**. But another reality of change is that none of us like it. We are human beings, and we tend not to like change. So basically, I am talking about that **ability to stand out as a leader and drive the change**. Get the troops, get the team behind you, and get the management behind you, to enable that change, to convince the people to do what needs to be done; that is a critical skill.

Fundamental Skill

Continuous Learning

At the core of all of these, we need to understand and admit that **learning never stops**, that we have never finished learning, and that we constantly need to learn, unlearn, and relearn and also accept the fact that **we will never know it all**. The moment we think that we know it all, we have lost. It is as simple as that. There is a great saying: "If you are the smartest person in the room, change the room, because you are in the wrong room."

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The Impact on Supply Chain Networks of Shifting Demand and Supply Dynamics

John Gattorna and Deborah Ellis

1 Introduction

The supply chain networks that support national and multinational businesses—and even governments—are being reconsidered. The doctrine of efficiency that had predominated in many industries has been challenged by the extremes experienced during COVID-19. But the story did not start there! Even before the pandemic struck in early 2020, there were trends emerging that ran counter to the worldview embedded in the networks that had evolved in the 20–30 years before.

Initiatives such as the globalisation of sourcing; centralisation of manufacturing; reduction in the number of distribution centres; and rationalisation of suppliers have been driven solely by cost, scale, and efficiency objectives. As we will discuss later in the chapter, these have been facilitated by a long period of supressed global freight rates.

In parallel, however, there has been another incongruous trend emerging that runs counter to efficiency—increasing volatility. Prices of key inputs to manufacturing and logistics have been particularly volatile since the global financial crisis (GFC). Demand patterns have been shifting. And major natural disruptions impacting supply, demand, or both have been increasing, while cybersecurity disruptions have risen in frequency and impact, as systems became more integrated.

Although COVID-19 is recognised as a 'black swan' event, its impact on global supply chains is likely to last much longer than the pandemic itself, essentially because it has exposed the contradiction of increasingly lean supply chains within a systemically more volatile operating environment.

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In this chapter, we will explore in more detail some of the shifting supply and demand dynamics, how they might play out in terms of the shape of future supply chain networks, and what will be expected of the people who run them.

2 Supply-Side Shifts

The upstream part of the supply chain is facing what may turn out to be an inflexion point, driven by shifts in the dynamics of the operating environment and changes in the focus of businesses and government. We discuss some of the factors involved in these shifts below.

2.1 Supply-Side Rebalancing

The search for lower cost inputs and manufacturing locations, reduced transaction costs as systems improved and reduced trade barriers (especially after the entry of China into the WTO in 2001) have driven a period of intense globalisation of supply chains. Over the last 20 years, supply chains have become more extended—with inputs, manufacturing, and consumption often widely dispersed across the globe, but ironically more concentrated—with sourcing and manufacturing tending to cluster in locations with a competitive advantage for a particular category.

That concentration of supply nodes—dependence on a single supplier for a key input, reliance on geographically concentrated suppliers, a large proportion of inputs or outputs transiting through a single port or airport—are all now becoming understood as supply chain vulnerabilities.

While many well-regarded supply chain academics (e.g., Christopher, 2005; Khan & Zsidisin, 2012; Sheffi, 2015) have been highlighting the risks embedded within global chains for at least 15 years, it seems that little was changing on the ground. COVID-19 was the extreme event that changed the paradigm—and it has delivered an awakening at the most senior levels in businesses and governments to the exposure embodied in current sourcing networks.

And with this recognition comes the expectation that supply chain teams will be factoring supply-side resilience into their decision-making much more consciously than in the past. Inevitably, this will change the profile of sourcing in the most exposed industries.

2.2 Next-Generation Manufacturing

Meanwhile, a steady stream of next-generation manufacturing innovations has been moving into the mainstream and changing the location and scale assumptions that underpin many networks.

The long-term trend towards increasing levels of automation and robotics has been reducing the labour component in manufacturing and thus the arbitrage advantages of low-cost countries. Growth in annual shipments of industrial robots, for example (defined as the 'low-volume, high-complexity' end of the automation categories), has been tracking at around 19% per annum from 2012–2019 (Teulieres et al., 2019).

Additive manufacturing, or the industrial application of 3D printing, was a $US1 billion industry in 2014. By 2020, it was a $US14 billion industry, and it is expected to grow at a compound annual growth rate of 21% in coming years (Grand View Research, 2021). Aerospace, automotive, health care, and defence were early adopters, but the range of industry applications is now expanding quickly driven by large, reputable organisations such as GE. Its significance from a supply chain network point of view is the shift it enables from making to stock in least-cost, centralised locations, to making on-demand closer to the customer. It is particularly attractive for low-volume products and parts, and opens up opportunities for customisation without the cost penalty that this would normally entail.

These manufacturing trends are changing the economics in many industries and will reinforce the risk-based drivers going in the same direction. Traditional strategies built on economies of scale through concentration of production in several large facilities that served global markets, can now increasingly be replaced by geographically dispersed factory networks that are more resistant to disruption, with the added benefit of shorter customer lead times.

2.3 Protectionism and Macro-Trends

Protectionist rhetoric and the trade tensions and tariffs that followed started to shift global flows off their long-term trend in 2019. The WTO reported that merchandise trade volume declined by 0.1%, a significant shift from the strong annual growth experienced since the GFC in 2008–2009, which averaged 2.3% and had been closely tracking world GDP growth (WTO, 2020).

Although trade recovered dramatically in late 2020, the expectation of many is that the focus on domestic manufacturing and self-sufficiency on strategic inputs since COVID-19 will reinforce the pattern emerging beforehand. Manufacturers are likely to be incentivised to increase domestic production, grow local jobs, and reduce dependence on politically risky sources.

The other factor that is coming into sharper focus, particularly as large funds and investors are starting to pay attention to it, is sustainability. Many leading grocery multinationals are getting serious about reducing the 'food miles' embedded in their products, and making plans to reduce CO_2, irrespective of what governments are legislating. And most large public companies in Europe and the USA are now reporting their environmental impact and agenda alongside their financial results.[1] (Governance & Accountability Institute, 2020).

[1] In 2019, 90% of companies on the S & P 500 were publishing a sustainability report.

2.4 Volatility of Inputs

In 2017, Christopher and Holweg published an update to their original Supply Chain Volatility Index (SCVI) of 2011. The index tracked the history of a basket of supply chain inputs (including copper and crude oil prices and the Baltic Dry Index representing bulk sea freight) as an indicator of the level of volatility in the supply chain operating environment. What they found was that the level of input volatility had steadily increased from 1970 to 2016. Within that the GFC caused a major 'blip' with wild swings, and this would obviously be replicated by COVID-19. The post-GFC period (from 2009 to 2016), however, was notable for the much higher bandwidth in turbulence than seen in the decades prior (Christopher & Holweg, 2017).

In another study, investigating volatility, Hu et al. (2020) studied the long-term price movements of three commodities—soybeans, crude oil, and gold. They also identified changing patterns and more volatility, particularly since the GFC, that went far beyond the explanatory power of the traditional models based on the global imbalances of supply and demand.

2.5 Transport Economics are Shifting

The reliance on extended global supply chains has been facilitated by a lengthy period of suppressed global freight rates.

Until COVID-19, container shipping costs had been falling for a decade, driven by excess vessel capacity. The China Containerised Freight Index, for example, based on the freight rates and volumes from 12 Chinese ports to locations around the world shows that it was less expensive to ship out of China in 2018–2019 than at almost any time in 2010–2012 (CCFI in MacroMicro, 2021).

Although seasonally variable, average airfreight rates have also been flat, held back by the belly capacity increase that has accompanied rapid passenger growth in the last decade.

Long-term constrained freight rates into the USA and Europe had enabled decisions about sourcing from Asia to be made with relative confidence.

This situation changed dramatically in 2020, however, as reactions to the various COVID-19 stages impacted. Early shortfalls in manufactured supply, surges in consumer demand, withdrawals of shipping capacity, containers caught in the wrong place, and grounding of much of the international passenger aircraft fleets combined to create extreme volatility in global logistics resulting in capacity shortfalls in both container shipping and airfreight, and dramatic rate increases as a result.

At the time of writing, it is not clear how this is going to play out post-COVID-19; however, one indicator is the strong upturn in orders for new container vessels. Increased optimism in the shipping industry, reflected by a significant increase in orders for new (mainly large) container vessels,[2] suggests that the shipping companies expect rates to settle at a higher level (DHL Global Forwarding, 2021). The long period of restrained global logistics costs may have come to an end!

2.6 External Shocks Are Becoming More Frequent

A series of events that have severally impacted global supply chains is now looking more like a pattern than one-off events. A major earthquake and tsunami in Japan in 2011 impacted electronic components for the automobile industry, and the silicon wafer inputs to semiconductors. A little later that year in Thailand flooding swamped factories making approximately a quarter of the worlds' hard drives, with severe impacts on the personal computer industry. In 2017, Hurricane Harvey led to shortages of resins and key plastics across many industries, when it hit US oil refineries in Texas and Louisiana. Interspersed with these wider events have been more localised disruptions including the ash clouds from volcanic eruptions in Iceland shutting down European air routes and massive bushfires in Australia impacting upstream food production and retail supply lines.

A study by the McKinsey Global Institute (Lund et al., 2020) indicates that supply chain shocks are becoming more frequent and severe. For example, they cite forty weather disasters in 2019 that led to damages exceeding $US1 billion each. They also point to the increasing potential for geopolitical issues to lead to disruption—via trade disputes and through reliance on less politically stable sources. In 2018, the share of world trade conducted with countries in the bottom half of the World Bank's political stability measures was 29%, up from 16% in 2000, and 80% of trade involved countries with declining political stability scores.

McKinsey's industry research in four heavily globalised industry sectors[3] suggests that a disruption lasting more than a month hit on average every 3.7 years (Lund et al., 2020). And modelling extrapolates their research to forecast that, without mitigation, companies with global value chains can expect to lose 42% of a year's EBITDA every decade from supply chain disruptions. In effect, they are saying that we have entered a new age of higher volatility, which has to be managed if growth and profitability are to continue.

2.7 Cybersecurity Risks

Technological advances in the last decade have increased the exposure of global and national operations to cyber-risks, leading to serious concerns at both the corporate and government levels. Aggressive private hackers and state-sponsored cyberwarriors appear to be able to stay ahead of the best efforts of companies and

[2] The order book-to-fleet ratio jumped from 8.8% in late 2020 to 14.2% in early 2021.

[3] Pharmaceuticals, automotive, aerospace, computers, and electronics.

governments and their detection capabilities. The economist has likened the supply chain security situation they see looming to an arms race (The Economist, 2019).

Supply chains are highly vulnerable. There is typically reliance on multiple internal systems, many now hosted on the cloud; increasing levels of integration between them; and dependence on the IT of numerous logistics providers.

A good example of the havoc that cyberattacks can impact on a business and the customers it serves is the damage caused to the Toll Group in Asia Pacific. Toll is a logistics business, owned by Japan Post, and it has been the subject of two ransomware attacks in 2020 (Smith, 2020). During the first of these, Toll had a period of more than a month with limited systems and was not even able to tell customers the location of their freight. These attacks incur significant costs as companies strive to switch to manual and alternative means to keep their business running. The damage to long-term customer relationships is difficult to calculate, but likely to be high.

3 Demand-Side Shifts

But shifting dynamics are not confined to the supply side. On the customer side also, there are changes to the patterns of consumer and industrial demand that will impact the supply chain networks needed in the future.

3.1 Buying Patterns

At the consumer level the growth of e-commerce, and the expectations set by the behemoths Amazon, Alibaba, JD.com and Lazada for small, fast deliveries has been one of the most important shifts impacting the design of supply chains in recent years. From a network perspective, the result is more distribution points, with higher reliance on express shipments. The Amazon fulfilment centre network shows the density required to support next day (and in some cities, same day) deliveries. In 2020, it was reported to have 110 fulfilment centres in the USA, with plans to open another 33 (Rattner & Palmer, 2020).

The retail omni-channel strategy that has emerged to respond to, and leverage, the switching behaviour of customers also has implications for supply chain networks. Sophisticated omni-channel operations optimise fulfilment of each order across both the store and distribution centre network. The role of the store thus changes—outbound staging and despatch come into focus. Systems and processes usually associated with distribution centres will be increasingly required at store level, and it is likely that space allocation will adjust between front of store and back to accommodate more reverse flow.

For online grocery, the store role is extending further, with investment in automation to create micro-fulfilment centres (MFCs). Albertsons, the large North American retailer and Woolworths, the major Australian chain, for example, are both pursuing store-based MFCs.

3.2 Shifting Consumption

From a global perspective, the balance of demand is shifting. Key economic and social indicators point to the increasing importance of Asia as a consumer of world production. The 10-year average world GDP growth rate to 2019 was 3%, but within that average lie two stories: the Asian leader's story with average GDP growth in China at 7.7%, India at 6.7%, Vietnam at 6.3%, and Indonesia at 5.4%; contrasting with the mature economies such as the US at 2.3%, EU at 1.6% and Australia at 2.6% (The World Bank, 2019). These differing rates of growth inevitably impact the centre of gravity in global flows of merchandise and materials. It is estimated that 50% of global GDP will be generated by Asia in 2040, and the continent will represent 40% of global consumption (Tonby et al., 2019).

As consumption rises, more local production in Asia is destined for the local market or for the region. While in the period 2007 to 2017, for example, China's production of labour-intensive goods increased from $US3.1 trillion to $US8.8 trillion, the proportion of China's gross output that was exported dropped from 15.5% to 8.3% (Tonby et al., 2019).

3.3 Volatility of Demand

The more volatile supply environment was considered earlier, but events during COVID-19 illustrated how demand patterns can also be very unpredictable when there are disruptions to the external environment. Demand for products with very stable buying habits can spike when insecurity about future access intervenes. New daily routines, such as working from home, change the consumer's focus and buying priorities, and readily-available brands substitute for preferred brands under pressure. These shifts are difficult to forecast, and the fallout creates a bullwhip effect impacting for months after the original disturbance.

Long and complex supply chains are disadvantaged when demand shifts. Increasing awareness of revenue at risk from external fluctuations will add to the pressure for supply chains to be able to explain their resilience strategies and will make it easier to justify higher safety stocks or manufacturing closer to markets.

3.4 Contribution to the Top Line

While consumption and consumers are changing, there is also a growing understanding that the supply chain is potentially a lever for actually increasing demand, not just responding to it. The lesson from the e-commerce companies is that consumers place a value on short lead times and on reduced 'friction' in the buying process. Supply chain plays a critical role in delivering on both value propositions and thus on revenue growth.

It has also been argued that in a time of capital abundance and a low cost of capital, as has been experienced since the GFC, the relative returns favour investment in growth vs improving profit margins (Mankins, 2017).

4 Impact on Supply Chain Networks

As pointed out by Christopher and Holweg in their 2017 paper on volatility (Christopher & Holweg, 2017), supply chains have a ‘centre of gravity’ which is the net effect of the various supply and demand-side forces that they are subject to. This centre of gravity then impacts the ‘ideal’ network of manufacturing and distribution facilities and their strategic inventory positioning.

As discussed earlier in the chapter, there are trends and shifting strategic priorities that are impacting both the supply and demand-side vectors—and thus are likely to shape the supply chain networks and arrangements of many firms in the next decade.

Overlaid on these forces are the goals and expectations that form the context of a supply chain network. Increasing awareness of risk—including the real and reputational risks associated with climate change—and a growing understanding of the supply chain as a lever for growth, likely lead to a new set of expectations from investors and senior leadership teams.

Rather than a cost minimisation objective only, the network needs to be considered as a multi-objective optimisation problem—with resilience, sustainability, and growth added to the traditional cost metric that has predominated in the past two decades.

With this broader view in mind and considering the ‘centre of gravity’ effect, some likely features of future networks are examined below.

4.1 Widening of the Supply Base

The most significant and visible impact of the COVID-19 crisis is likely to be the diversification of the supply and manufacturing base, as companies consciously seek to reduce sourcing risk. Some multinationals are pursuing a ‘China plus one’ strategy. Where the incumbent supplier(s) or plants are located in China, a second supplier or facility in a different geography is being actively developed. This will benefit the next tier of supplying countries with similar economics such as Vietnam, Sri Lanka, and Mexico.

To support an orderly approach to de-risking sourcing, supply mapping and risk profiling must become a higher priority. And this will require visibility deeper into the supply base—to second- and third-tier suppliers, in order to identify the level of geographic concentration and the vulnerabilities embodied in the network.

Contrary to common wisdom, complexity of supply networks is starting to be understood to have some benefits. Although complex networks can be more opaque, they can also provide companies with in-built redundancy and flexibility. Modelling by CSIRO in Australia on agriculture supply chains, for example, indicates that complex networks, defined as having a large number of nodes and links, are more resilient to disruption (Lim-Camacho et al., 2017).

4.2 Increase in 'Local for Local' and Regional Production

Several of the forces identified earlier are pulling production closer to the consumption point. In Asia, it is the natural evolution of growing consumption absorbing local production. In Western economies, it is a combination of risk management, changing manufacturing and scale economics and more sophisticated supply chain strategies that focus on revenue as well as cost.

On the revenue front, some organisations had already embraced a dual-sourcing strategy, splitting production of the same items between a low-cost location (lean) and close to the market (agile). An Australian swimwear company has been able to grow market share and reduce discounting by pursuing this strategy (Gattorna & Ellis, 2020a). This parallel approach is also a risk mitigation strategy.

Pharmaceutical and other critical suppliers will likely see government incentives for more local production. The US Executive Order 14017 on America's Supply Chains (2021) issued in February 2021 by President Biden exemplifies the pro-active stance that governments are pursuing to increase the resilience of their domestic economies.

Automation and developments in manufacturing that are not so scale dependent will reinforce the shift to local production.

More local production would be expected to reduce the length of supply chains and make them less susceptible to disruption (potentially, of course, at a higher cost).

4.3 More Use of Strategic Buffers

Inventory has long been the target of supply chain 'best practice'. Operations have been assessed on their inventory turns—the mantra was always the higher the turns, the better the operation. But increased sensitivity to risk is leading to a reassessment of the strategic role of inventory as a buffer.

Even without a strategic change in direction, those managing their safety stock in a 'statistical' (vs rule of thumb) method will likely see the higher demand and supply variability of recent years flow through into higher levels of safety stock. But there are many organisations that do not take a statistical approach to inventory decisions—and in a more volatile environment, these businesses are the most likely to struggle and lose sales (the authors have found the '2-week safety stock' rule of thumb alive and well in many diverse businesses).

Higher buffer inventory does not necessarily have the adverse financial impact that conventional supply chain wisdom suggests. An analysis of 1500 public companies over 20 industries indicates that within an industry those companies with higher market capitalisation are more likely to have lower than industry average inventory turns (Thomas, 2021). Or conversely, better performance is often associated with more—rather than less, inventory!

4.4 More Flexible Networks

It is apparent that the inherently more volatile regular operating environment and the higher incidence of external disruptions both require supply chain networks that can flex and adjust more quickly than in the past. This has been called 'structural flexibility'—the ability of a business to promptly reconfigure its supply chain in response to changes in the business environment (Christopher & Holweg, 2017).

Structural flexibility has implications all along the chain: from the contracts with suppliers and third parties, to the make vs buy decision, to the lease terms on distribution centres to the configuration of manufacturing plants—and to the organisation structure and mindsets of the teams that manage the operation.

To design the entire supply and demand network as a completely flexible ecosystem, however, is unrealistic, and thus, the authors in earlier work have looked to use a portfolio approach, designing a range of tailored supply chain solutions to maximise in-built flexibility for 'business as usual' without needing dramatic shifts in strategy to respond to each new shift in the market or the external environment (Gattorna & Ellis, 2020a).

4.5 Tools and Mindset Shifts

Structural flexibility also requires tools and mindsets to enable changes in strategy and responses to disruption to be assessed and implemented quickly.

It was apparent during COVID-19 that experience came to the fore—because the forecasting and planning models that utilised historic patterns could not reflect the unprecedented situation that most organisations faced. But, just as in public health decision-making where the most effective decisions were those that combined deep experience with modelling, supply chain network decisions are often too complex for experience alone.

The optimisation models that are built for network design are well suited to the testing of scenarios around a range of supply or demand conditions and thus are natural tools for decision-making in such situations. But rather than the annual/semi-annual update that is suitable for strategic planning, these models need to be kept up to date and in a 'ready-to-run' state to enable fast decision-making when required (Gattorna & Ellis, 2020b). In some industries, such as mining, where the supply chains are capital intense, simulation models may also be needed to understand the impact of different options.

The corporate mindset to enable fast decision-making, and changes in direction when required, is perhaps a bigger obstacle. In a more volatile operating environment rigid hierarchies, static processes and tightly controlled limits on autonomy within the operation constrain the flexibility and speed of response needed to adjust

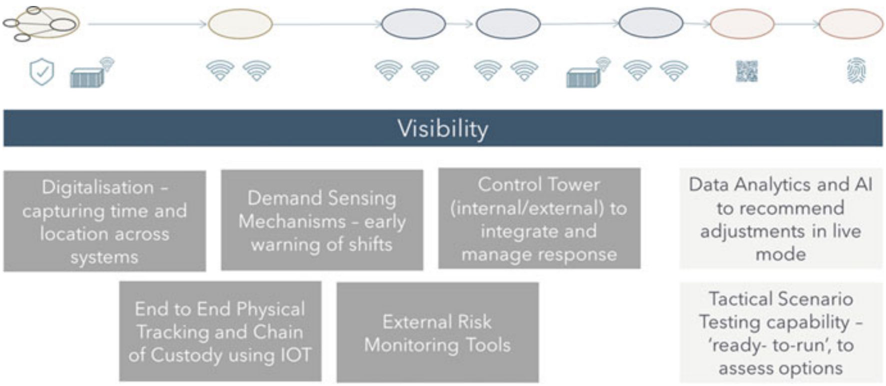

Fig. 1 Developments supporting improved network visibility and pro-active management (Gattorna & Ellis, 2021)

as shifts occur. Building the capabilities and organisation structures that support fast decision-making rhythms and thus organisational 'clock speeds' are a fundamental focus for more resilient supply chains and have been a theme pursued by the authors in previous work (Gattorna & Ellis, 2020a).

4.6 Visibility

The ability to make quality decisions and adjustments across the supply chain network is also highly dependent on visibility—knowing where product is, knowing how demand is changing, and knowing as soon as a disruption occurs. This has been a major barrier to the ability to respond quickly to disruptions in the past, but the developments around IOT, the emergence of integrating software to connect internal functions and external providers, the rise of the external risk-monitoring software,[4] and the development of the 'control tower' concept and capability are all key planks in improving the end-to-end visibility of the supply chain network. Control towers enable real-time decision-making when deviations occur and give confidence when they do not. Figure 1 below captures some of the developments that will significantly improve supply chain visibility in the next decade.

4.7 A Parallel Universe of Supply Chain Management

The supply and demand volatility discussed earlier in this chapter effectively fall into two categories. There are the extreme events, such as fires, floods, and pandemics—which although all indications suggest are becoming more frequent, are intermittent,

[4] To monitor weather events, port congestion, etc. (e.g., Resolution360).

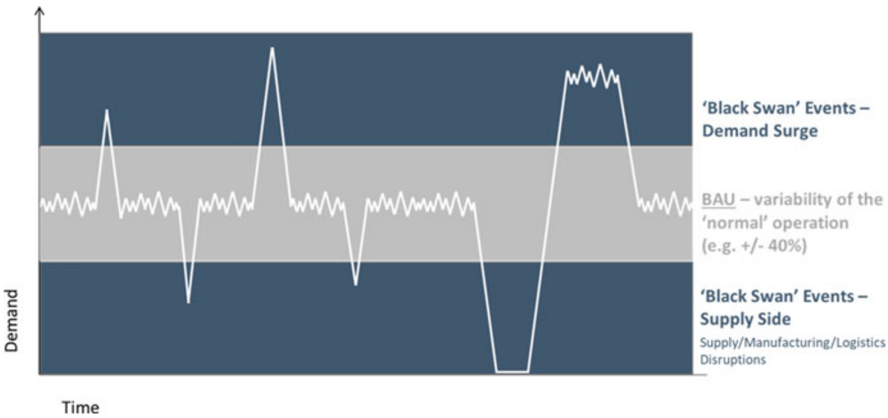

Fig. 2 'Parallel universe'—managing two levels of supply chain variability (Gattorna & Ellis, 2021)

and basically not forecastable. Then, there is the more day-to-day volatility embedded in the supply chain—in input prices, shipping delays, supplier reliability, demand shifts—which also appear to be increasing, but which the established supply chain network needs to be able to accommodate.

To address the two levels of volatility that are now evident in the operating environment, it is proposed that larger businesses need to design their supply chain networks at two levels, i.e., a small portfolio (3–4) of supply chain configurations to cope with *business-as-usual* (BAU) levels of volatility (say ±40%) and an additional configuration to specifically address the onset of extreme disruptions. Classically, the BAU supply chain network will need at least a Lean supply chain for customers who prioritise price and reliability and an agile supply chain when demands are more dynamic—where speed and responsiveness are essential (BAU may also need a Collaborative Supply Chain™ to work closely with key customers and a Campaign Supply Chain™ for major projects.)

The Fully Flexible Supply Chain™ is the set of capabilities and the team that monitors and manages the more extreme disruptions.

The two aspects of the 'parallel universe' that supply chain networks need to accommodate in a more volatile operating environment are depicted in Fig. 2.

5 Implications for the Skillsets Supply Chain Management Will Need in the Future

With the rapid changes taking place in the global operating environment, the skillsets required to manage enterprise supply chains are changing accordingly.

5.1 Heavy-Duty Analytics Is Core Business for the Future Supply Chain

The decision-making in supply chains of the future will depend on the rapid, often real-time use of data to drive ever faster and better-quality decision-making. Master data may well be owned by the supply chain function (due to the high dependency it has on this data), and it is likely many operations will be overseen by control towers that rely on a set of algorithms to monitor data, provide alerts and recommendations, and ultimately automate some categories of response—but they will also rely on results-oriented managers who can utilise the information and make quick decisions.

In the strategic and tactical (1–3 month) planning horizons, decision-making is heavily dependent on analysis of patterns. In a more volatile world where uncertainty is an underlying assumption, this planning needs to become increasingly refined. Assessing probabilities and overlaying statistical interpretations of data become important, beyond just depicting data in visualisations.

As increasingly sophisticated systems are added into the mix, such as machine learning-based forecasting or AI-driven planning recommendations, there is a need to understand, specify, and assess the new breed of techniques and systems and to call out when systems are not performing. All these interactions will require a reasonable level of analytical acuity.

Shifting to a more data-driven way of operating is not only about bringing data scientists into the supply chain fold, but it requires education of the broader supply chain management team regarding what is possible, the questions to ask, the systems that fit, and how to manage analytics and data science professionals in order to get full value from their capabilities.

5.2 Operations Research Skills—to Bring More 'Science' to Bear

And taking the discussion of analytics one stage further, it is worth thinking about the 'science' that is most closely aligned to the problems faced by the supply chain—operations research. Topics such as queueing theory, game theory, and optimisation are highly relevant, but rarely the subject of senior management attention or a focus for recruitment.

At the very least, every reasonably complex business needs a modelling team to support sourcing, manufacturing, and logistics. This group, including operations researchers, would drive design and redesign as conditions change, test various scenarios to safely assess options before committing to actions in an uncertain environment, undertake risk assessments, and determine where to locate buffers of different types along the supply chain.

Mapping and modelling of suppliers and using techniques such as indexing to prioritise risk will also increasingly fall to a modelling/operations research group.

5.3 Leveraging the Financials

Supply chain performance has been disproportionately focused on cost in the past—but its impact extends to revenue, margin, and the balance sheet and relates to both the current situation and future financial viability—through the level of embedded resilience and the sustainability of the business model. These wider dimensions introduce more complex trade-offs, and managers and teams will need to be able to make assessments and justify their decisions in financial terms to win support for change.

Many roles in the supply chain are currently isolated from the wider financial implications of their decisions. There is a case for stronger financial skills across supply chain professionals to enable short- and long-term decisions to be more transparent and informed.

5.4 Digital Architecture

As digitalisation and automation have been adopted along the supply chain to date, the initiatives have typically been assessed in isolation. As these initiatives start to join up and as systems have a wider span (such as the integration layer needed to support a control tower) and AI systems emerge that can 'do anything', there needs to be a significant design element injected. New roles that work at the intersection of the supply chain and the IT architecture will be required. The term 'automation architect' has been coined to describe this new role and skillset (Gartner as cited in Runyon, 2021), although perhaps the more general term 'digital supply chain architect' might better describe the gap they would be filling.

5.5 Cybersecurity Governance across the Chain

To address the increasing concerns regarding systems and digital exposure it is expected that new functions and roles will also be needed, focused specifically on these risks. Boyson (2014) has proposed a construct that is titled Cyber Supply Chain Risk Management (CSCRM) that holds responsibility for monitoring risk within the focal organisation and across the extended partners including Tier 1 and Tier 2 suppliers, logistics providers, and customers. It would cover IT risks and the human factors that can lead to exposure.

This is inevitably a growth area, and whether a part of the supply chain team or IT, there will be strong demand for people with appropriate skills.

5.6 Cross-Functional Career Paths and Structures

Many people who work in supply chain roles start life elsewhere in the organisation, often in manufacturing. While this is valuable to appreciate internal dynamics, career paths that also include exposure to the front end of the business and thus to customers are of particular value when working in the part of the business that serves them.

New organisation designs are also needed to embed a cross-functional mindset in the business. Current functional arrangements are now inadequate in the face of a volatile operating environment and demand for shorter lead times coming from customers. Keep in mind that while businesses continue to manage vertically, customers buy horizontally, thus without consciously creating structures to align across the functions they are at a 90-degree misalignment with the ultimate task of servicing and satisfying customers.

5.7 Square Pegs/Square Roles

To compete strongly in the future, it is clear that supply chains will need to become more refined—with a range of service offers and operations rather than a 'one-size-fits-all' approach. To be successful, differentiation requires distinct types of teams to drive a range of different strategies towards a target market.

This will require combining different roles and mindsets to achieve an overall result—and using different leadership styles to shape the outcome. The fully flexible capability, for example, requires creativity, fast decisions, and a pro-active style of operation, while the lean supply chain is more about reliability, routine, and low cost. Without embracing these nuances, differentiation falls down at the implementation stage. Despite all of the advances in technology, it will still be the people side that makes or breaks a supply chain strategy.

5.8 Creativity and Innovation

The skills mentioned so far in this chapter could be described as biased towards the pragmatic and analytical – what Kahneman (2011) describes as System 2 thinking. But sophisticated supply chains in the future will also need to ensure that they have, and support, creativity and innovation. It is clear that adaption to a volatile operating environment, managing to multiple objectives and finding ways to leverage new technologies in the service of the operation and the customer, will place demands on supply chain teams that go beyond reasoning and experience alone and draw on the more intuitive competencies.

The need for a dual capability enabling the organisation to be continually refining the current operational 'algorithm' while developing the next 'heuristic' has also been advocated by Roger Martin and the Design Thinking Movement (Martin, 2009).

5.9 General Management

For many global product companies, the majority of capital investment is tied up in supply chain assets (manufacturing and distribution), and more than half of working capital is related to procurement and inventories. That being the case, it is fair to say that as enterprises undertake significant changes in their supply chains, they are in effect transforming the overall business, such as the dominance of supply chain-related factors.

Senior leaders in the supply chain have enormous scope for impacting the business in the coming decade but are inevitably operating in a more ambiguous context. They will need to be generalists—with deep knowledge of customers, enough systems, and financial acumen to negotiate a path through the digital opportunities and risks, and an ability to harness innovation—all in addition to their functional skills. And they will need to be able to inspire and lead their teams to manage multiple objectives in an increasingly complex and volatile operating environment.

Management Perspective on the Shifting Demand and Supply Dynamics Impacting Supply Chain Networks
Scott Phillips
ECCO Shoes, Toa Payoh, Singapore

Interview with Scott Phillips, ECCO Shoes (13 May 2021).

Scott Phillips is the Global Supply Chain and Sourcing Director for ECCO Shoes, based in Singapore. ECCO is a Danish private company, manufacturing and selling premium branded shoes and leather goods. They operate 2500 of their own stores worldwide and employ 21,000 people. ECCO's experience and decisions in recent years reflect many of the trends discussed in Chap. 2.

Prior to COVID-19, were there any shifts in demand, or changing demand patterns, that were impacting ECCO's supply chain?
Europe and USA are now mature markets for ECCO, and organic growth is slowing, while Asia has been growing very strongly and has become a key region for us. ECCO is seen in Asia as a premium Scandinavian brand, and the product is positioned more towards the luxury end. China has become our largest market—it really took off around 2015.

In the 10 years prior to COVID-19, were there any significant shifts in your manufacturing footprint or sourcing policies?
We had made shifts from mainly European-based manufacturing to significant levels of Asian production in the late 1990s/early 2000s. We opened plants

(continued)

initially in Thailand, followed by Indonesia, China, and Vietnam. They became increasingly important as demand grew, especially in Asia. Thailand was a very significant location for us with 35% of our production until the severe flooding in 2011, when our factory was completely submerged under water. Since then, we have a risk management policy that limits the amount of production that can be sourced from any one plant. We rebuilt on the same site, but at half the capacity—and the government has constructed a large dyke around the industrial area. (Scuba divers had rescued some of our special machine tooling—which was no easy task given that the snake and crocodile farm 1 km away had also flooded!). The Indonesian plant was expanded after this event to make up for the lost capacity. The floods proved to be an important strategic wake-up call for us and led to a much more proactive stance regarding supply chain risk.

Post-COVID-19, have your sourcing/manufacturing strategies changed or do you expect them to change?

Like many others, we faced very big challenges during COVID-19. Although we had strong relationships with our first-tier material suppliers, who came through quite well, we have supply interruptions caused by second- and third-tier suppliers. We also struggled with the common logistics challenges—airfreight was difficult to obtain and very expensive; cross-border ocean freight reliability was at an all-time low, and lead times were longer than usual. There were so many changes to schedules that we were constantly replanning right across the operation. COVID-19 exposed the vulnerabilities and has changed our thinking. We are now developing a more localised sourcing strategy. We will shift from a significant dependence on Chinese raw material sources, to a more diversified strategy—with more focus on local suppliers, e.g. Indonesian suppliers into the Indonesian plant. This is not easy—we source +6500 different SKUs/year; so, it is not straightforward to find the required breadth of supply locally. Diversification is especially difficult as ECCO operates to very high compliance standards with suppliers. We use three different levels of monitoring to ensure our suppliers meet our ethical and quality standards: our own team; an independent body in Denmark; and a third-party auditor for on the ground audits. We have also started doing more risk profiling at the country level.

Post-COVID-19 what do you expect to happen to the patterns of demand and to your channels?

We were already experiencing growth in e-commerce, but during COVID-19 it really took off, and we expect it will stay at much higher levels than in the past few years. We have taken some investments away from store expansions into investing more in the e-commerce platforms. This will mainly be via our

(continued)

own sites, although we operate a hybrid strategy, using the major platforms and with customers selling through their own sites.

Do you envisage any major changes to your global networks—from any of the above or other factors?
We expect to reconfigure our supply chain network as a result of the changes in channels and our shifting supply and risk strategies. We will likely re-position distribution centres (DCs) in the coming months and years. We will try to remain asset lite (not buying DCs or taking long leases) to maintain flexibility. We are also more conscious of ensuring we have the logistics capacity we need, when we need it, and are setting up more direct contracts for space and equipment with the ocean carriers, for example.

Thinking about ECCO's future network and supply chain strategy, what are the skills that will become/are becoming more important?
It is not so much the skills, but the mindset we need that is changing. We are finding that we need more flexibility in thinking, more adaptive learning—whatever the role. The hard-core functional specialist is not well suited when the environment is constantly changing and when each role needs to consider the impacts elsewhere. Planning needs to understand sourcing; logistics needs to understand manufacturing. There is no one way to have a supply chain career now! The soft skills are really coming to the fore also, especially stakeholder management, and storytelling/selling the idea—it is hard to be changing often if you cannot convince those with a stake to go with you. And analytics has been increasing in importance for some time. Mind you, all the data warehousing and automation was not enough mid-COVID-19—we still found ourselves going back to 'hunter and gatherer' mode and turning to the Excel wizards!

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AI in Logistics and Supply Chain Management

Robert N. Boute and Maxi Udenio

1 Introduction: Digital Logistics

Artificial intelligence (AI) refers to the ability of a computer or computer-controlled robot to perform tasks commonly associated with human beings. The use of the term *intelligence* in AI implies that the task being performed by a machine, script, or algorithm would require the use of intelligence, were a human to do it.

Although AI has been around since the late fifties, it has only become a mainstream concept since the last decade. AI now powers our smartphones, our TV recommendations, and even our photo libraries. Also in business, AI has transformed from an obscure term to a buzzword. In a 2021 survey by Accenture, 77% of executives state that their IT architecture is becoming critical to the overall success of the organization.[1] In the healthcare sector—transformed in 2020 by the COVID pandemic—the confidence in AI is even stronger. Reportedly, 98% of healthcare executives have developed an AI strategy plan, among which 44% have already implemented an AI strategy.[2] Other business surveys are similarly strong. McKinsey, for example, notes that nearly 58% of executives surveyed have already embedded at least one AI capability in their company.[3] The message from the industry is clear: AI is here to stay, and the companies that learn how to adopt and scale it are poised to enjoy a competitive advantage.

[1] Accenture: Technology Trends 2021. https://accntu.re/3nN0ABW

[2] third Annual Optum Survey on AI in Healthcare. https://bit.ly/3azuVOU

[3] McKinsey global AI survey. https://mck.co/3auUtN5

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In logistics and supply chain management, analytics and computer support have been around for decades. Supply chain planners, for instance, use software tools that process historical data to forecast demand; many enterprise resource planning (ERP) systems automate the decision of when and how much to order; and warehouse and transportation management systems optimize storage and transportation operations. Each of these supply chain support tools can be run as a siloed application or integrated with other business operations, such as financial accounting or supplier relationship management. Integration facilitates data sharing to a common data platform. When the platform is also accessible over the Internet, Web-based tools provide remote access and connectivity with third-party applications through application programming interface (API) software. Cloud-based service offers the additional flexibility to scale up IT infrastructure to accommodate temporary computing needs.

The recent breakthrough in digitizing logistics operations comes from real-time connectivity of assets to the data platform: Machines, vehicles, and devices can now be monitored via sensor technologies that capture all sorts of data in real time. In addition, when sensors become impractical, operators can provide feedback information through mobile and wearable devices. This extensive connectivity is known as the fourth industrial revolution, also referred to by the term *Industry 4.0*.

Such connectivity provides (quasi) real-time visibility over all workflows. A “digital control tower,” in analogy to the airport control tower, can provide visual alerts that warn of inventory shortfalls, or process bottlenecks, before they happen. Using simple control algorithms, teams on the front line can course correct even before potential problems become actual ones. Furthermore, the availability of historical data can give rise to increasingly sophisticated algorithms which add additional intelligence to the control rule: Predictive analytics learn from historical data to obtain patterns and correlations not evidently detected by humans. By means of a *digital twin* of its physical operation, real-time analysis and optimization can even prescribe decision making where users make decisions based on what intelligent agents recommend.

The digital control tower providing real-time information, potentially augmented by predictive diagnostics and analytics, may support logistics and supply chain managers in their decision making. As we discuss in this chapter, these “smart” decisions have the potential to bring about more efficient, more resilient, and even more sustainable supply chains. Observe, however, that these AI tools do not necessarily perform an entire workflow. Instead, each delivers a predictive component to assist someone in making a decision. AI can take over some, but not all, tasks. In fact, in the majority of supply chain AI implementations to date, humans still have the last word. AI does not imply—by itself—autonomous decision making (Boute and Van Mieghem, 2021).

2 Smart Logistics

Back in 2017, The Economist published an article titled, “The world’s most valuable resource is no longer oil, but data” (The Economist, 2017). The use of digital applications as well as the connectivity of assets through, e.g., sensors and digital control towers, generates large amounts of data (possibly in real time). The question that now arises is how such data can be leveraged to improve the level of *intelligence* of logistics and supply chain decision making. Notice that the use of data in logistics is not new—we have been transporting goods around the world based on data-driven forecasts for decades. What is new is the sheer volume of data that we now generate, store, and share. These data have the potential to make logistics and supply chain control more adaptive and *smarter*.

In traditional data-driven applications, one typically uses one or—at most—a few sources of data, such as historical demands or current inventory levels. As long as the input variables remain "countable," one can implement (or even program) if–then instructions to support (or even automate) decision making. The integration of various digital applications, in contrast, generates a data pool of different sources, collected automatically through sensors (*Internet of Things*) as well as manually through mobile and wearable communication devices (known as the *Internet of People*). When the number of data sources grows rapidly, the ensuing mountain of data makes the explicit enumeration of if–then instructions infeasible.

This is where machine learning comes into the picture. Whereas AI is the umbrella term for all computer rules that mimic human intelligence (including if–then instructions), machine learning is the subset of AI where an algorithm *learns* to mimic human behavior and makes its own decisions. Machine learning algorithms are in essence *prediction machines* that perform a task without using explicit instructions (Agrawal et al., 2018).

A milestone for the mainstream use of machine learning is the victory of the algorithm AlphaGo over the world champion of the Chinese board game Go, Lee Sedol, in March 2016.[4] The ancient game of Go is played on a board with $19 \times 19 = 361$ positions, each of which can contain a black, white, or no stone. It therefore has $3^{361} \approx 10^{172}$ possible states; several orders of magnitude more than chess,[5] and even more than the number of atoms in the universe. Due to the sheer number of possible states, devising explicit instructions (prescriptions) for how to play each state is impossible. Hence, Go was considered the holy grail of AI.

Instead of using brute force to calculate all possibilities, Alpha Go used machine learning and neural networks to mimic the learning process of a human brain. The system was not preprogrammed. Instead, it was fed data of historic games and allowed to play itself so as to improve its win rate through trial and error.

The same machine learning power can also be applied to logistics and supply chain management. To understand possible applications of machine learning, it is instrumental to differentiate between the different forms it can take. Broadly speaking, one can divide machine learning into supervised, unsupervised, and reinforcement learning.

[4] A breathtaking documentary of this victory is available at https://www.alphagomovie.com/

[5] Approximations place the number of possible states in chess at around 10^{46} .

2.1 Supervised Learning

Supervised learning is perhaps the best known (and most frequently used) type of machine learning. An extensive set of labeled training data with the "correct" answers, which serve as "supervisors," is used to estimate a "mapping function" f that *predicts* output Y based on a set of input data variables X. The mapping function is determined so as to minimize the prediction error s,

$$Y = f(X) + s.$$

The algorithm makes predictions on training data (i.e., data for which both X and Y are known) and continuously improves its mapping function by comparing its output to the "correct" answers in the training data. Learning stops when the algorithm achieves an acceptable level of performance.

The goal is to approximate the mapping function f so well that you can predict the outcome Y for *new* input data X. It is possible that the mapping function performs well on the training data and poorly on new data that was not encountered during its training. In such a case, there is a good chance that the model is overfitted. The most obvious remedy to avoid overfitting is to enlarge the training data set.

Supervised learning is, for instance, used to classify images. In such a case, an algorithm learns the mapping function based on a set of labeled images. Each time the algorithm is fed with new training data, the mapping function can be improved. This explains the importance of (lots of) data to train a good learning algorithm. The next time you are prompted with a "CAPTCHA"[6] when filling out a form on the Internet to prove that you are fully human, do know that your humanoid clicks are feeding supervised learning algorithms behind the scenes and, in doing so, improving object recognition of traffic lights, street signs, etc. The more labeled data you feed the algorithm, the more accurate it becomes. Thus, with each CAPTCHA we complete, we are implicitly contributing toward autonomous driving.

Supervised learning can be used in logistics to predict a multitude of observations:

- *Demand forecasting:* Given enough computation time and data instances, 1supervised learning can learn how sales are influenced by a wide variety of features, such as the marketing mix (price, promotions, discounts, advertising), seasonality, calendar events, weather forecasts, lagged sales data (sales from previous periods), and even social media reviews, using tools such as text mining and natural language processing (Cui et al., 2018).
- *ETA prediction*: Based on data from a transport control tower that tracks real-time information of the trucks and keeps track of the realization of the planning, one can build a predictive model to classify whether a truck will be on time or not.

[6]CAPTCHA stands for the Completely Automated Public Turing test to tell Computers and Humans Apart. CAPTCHAs are used to differentiate between real users and automated users, such as bots.

These data can additionally be complemented with external data variables, such as weather or traffic information (Kolner, 2019).

- *Throughput times at customs:* Based on a historical data set of packages that passed customs administration, one can predict waiting times at customs based on the characteristics of the package, such as source of origin, weight, and size (Flows, 2019).
- *Downtime prediction*: The time to failure, or remaining useful life, of (parts in) truck cabins, rail wagons, or machines can be predicted by integrating measurements from specific variables such as condition monitoring (e.g., vibration) and operational (e.g., usage) data in the estimation process (Si et al., 2011).

Supervised learning can also be used to predict cases in which a prescription made by a computer system is likely to be overruled by a human and adjust the original prediction accordingly. For instance, packing workers at e-commerce warehouses sometimes deviate from the order packing instructions (which items to pack in which sequence and in which box) prescribed by the system. These human adjustments are typically necessary to pack the box, but they increase packing time and reduce operational efficiency. By tracking when packing workers deviate from the system prescriptions, a machine learning algorithm can predict when workers are more likely to switch to larger (or different sized) boxes. By pro-actively adjusting the algorithmic prescriptions of those "targeted packages," the rate of switching to larger boxes—and thus the average packing time—can be reduced (Sun et al., 2021).

Another example where human decision makers approve or override algorithmic recommendations is in the review of sales forecasts. Even in cases where the algorithm is well-tuned (and thus overrides are rare), the human decision maker is still burdened with reviewing a potentially large number of recommendations. By analyzing a history of sales forecast reviews, a supervised learning algorithm can predict whether or not the decision maker will modify the recommendation and whether such a modification will improve or impair the performance of the system. Using these predictions, a significant portion of the order recommendations can then be automated with little, or even a positive, impact on performance, thereby freeing up the decision makers' time for other value-added activities (Imdahl et al., 2021).

2.2 Unsupervised Learning

Unsupervised learning algorithms *describe* patterns or groupings of data given a set of unlabeled observations, i.e., without knowing the correct answers. These algorithms are basically left to their own devices to discover patterns and information that was previously undetected. The goal of such analyses is to group a set of data points, such that data points in the same group or cluster are more similar to each other than to those in other clusters. Often, such clusters represent data groups with distinctive characteristics for which specific operational policies can be designed.

Customer data can be screened to discover groupings of customers according to, for instance, similar purchasing behavior or common profiles through similar combinations of customer characteristics. Likewise, product data can be used to cluster products into groups according to, for instance, their product life cycle stage. Such clustering can be useful for customer or product segmentation where a distinct logistics distribution approach or different target inventory levels are required. One can also customize the prediction model for each group to achieve higher accuracy (possibly combined with supervised learning). Policies or predictions based on clustering typically provide superior performance compared to unclustered prescriptions.

Unsupervised learning is also used to analyze customer orders to identify relationships or groups of items that are frequently purchased together. Such "market basket analysis" can, for example, be helpful to optimize product placement and layout in an e-commerce warehouse to, among other objectives, improve order picking productivity. A higher order picking productivity is one of the key drivers to reduce the cost to serve an e-customer.

Finally, unsupervised learning can be used to identify observations which do not conform to an expected pattern, known as "anomaly detection" or "outlier analysis," such as abnormal delays in transportation times. This detection can spur further analysis to predict—or even better: prevent—future delays.

2.3 Reinforcement Learning

Reinforcement learning is different from (un)supervised learning: Rather than predicting or describing an outcome, it *prescribes* which decision or action to take, based on the current state of the system, while taking the future impact of these decisions into account.[7] One could say it tries to predict the optimal action given the current situation. Reinforcement learning also requires training for the algorithm to *learn* how to convert inputs into outputs. However, instead of comparing the output directly to the "correct" answers (as in supervised learning), training a reinforcement learning algorithm relies on trial and error by simulating sequences of states, actions, and rewards. These simulations can be fed by either historical (real) data or simulated data, provided an accurate data generation engine. It is up to the model to figure out how to perform the task to maximize the reward, starting from totally random trials and finishing with sophisticated tactics and superhuman skills. By leveraging the power of search, performing numerous trials and reinforcing specific actions that generate high rewards (or low costs), the algorithm learns which actions provide the best results in any given state. In contrast to human beings, a reinforcement learning algorithm can gather experience from thousands of parallel trial runs if it is run on a sufficiently powerful computer infrastructure.

The aforementioned machine learning algorithm, AlphaGo, uses reinforcement learning. The same algorithms have the potential to also be applied in logistics,

[7] In mathematical terms, it formulates a problem as a Markov decision process, where an action taken in a given state transitions the system to a new state and generates a reward (or cost).

where the optimal decisions are unknown due to the sheer problem complexity and thus cannot be captured—or programmed—by simple if–then instructions, for instance:

- *Multi-Source or Multi-Mode Replenishment:* When you have access to multiple sources to replenish your inventory, reinforcement learning can support the decision of how much to replenish from a cheap offshore supply and how much to source locally at higher cost. Similarly, it can be used to combine multiple transport modes in parallel, where part of the shipment is shipped using a slow, but more carbon-friendly transport mode such as rail or waterways, and part of the shipment is shipped using a more responsive mode such as road or air freight (Gijsbrechts et al., 2020).
- *Joint Replenishment and Collaborative Shipping:* To synchronize the replenishment cycles of individual products or companies and facilitate collaborative shipping, machine learning algorithms can be used in a control tower setting that tracks the supply chain flows in real time (Vanvuchelen et al., 2020).
- *Perishable Inventory Management:* Managing inventory of products with an expiration date is notoriously complex, as one should not only take into account the inventory levels (and those in transit), but also the age distribution of the goods in inventory. As the optimal inventory policy for this problem is intractable in many cases, reinforcement learning algorithms can develop good performing heuristics through learning (De Moor et al., 2021).
- *Omni-Channel Supply Chains:* When managing inventory for multiple channels, reinforcement learning can prescribe how much should be stocked centrally to leverage inventory pooling benefits, which products to stock locally to ensure fast delivery and from which warehouse different customer orders should be filled.

These AI applications not only support logistics planners to improve their logistics costs, but also build more resilience into the supply chain through higher responsiveness and agility to real-time events or disruptions. Moreover, as we discuss in the next section, they may reduce the carbon footprint of logistic distribution systems without compromising on service levels.

2.4 Implementing Machine Learning Algorithms

Thanks to the open nature of the machine learning community, code for most (un)supervised and reinforcement algorithms is freely available online. Most algorithms can also be re-used in different problem settings with minimal changes. As a result, machine learning may be seen as a general-purpose technology where one is only required to outline the prediction objective along with the data sources (input variables) needed to make the prediction. There is no (or little) need to program the algorithm itself.

Moreover, as software development kits (a collection of software development tools in one package) are being designed to facilitate the interaction between programmers on the one hand and end users on the other, the focus of machine learning applications is reverting to the collection of (clean) data. Machine learning models thrive on the availability of (a large amount of) data. The more labeled data that can be fed to an algorithm, the better it becomes at generating accurate predictions.

What all machine learning algorithms have in common is that training an algorithm to learn good predictions or prescriptions can be computationally very expensive. Therefore, most applications resort to cloud computing. The flexibility and scalability of the cloud make it possible to temporarily utilize peak capacity in computing power in only those periods where the algorithms need to be trained.

Scale provides a significant advantage in machine learning. More data improves the models which, in turn, improve the data. Thus, larger firms with the necessary resources, as opposed to smaller ones, are typically at an advantage to develop superior models and improve their data collection, simultaneously creating a self-reinforcing loop. The best known examples of this scale advantage are Amazon and Google. We are aware that data-driven markets can lead to a "winner takes all" situation. The fact that industry giants, such as Amazon, have orders of magnitude more computing power at their disposal than the large majority of firms on the planet combined forces us to ask the question at what point the scale advantage is just too much.

3 Sustainable Logistics

The value of AI stems from its ability to (semi-)autonomously process data to produce predictions or prescriptions. In logistics and supply chain management, these are typically used with the intent to optimize operational parameters, such as customer service levels or inventory holdings. The same characteristics also make AI a powerful tool to improve other objectives—most notably sustainability development goals (SDGs).

The argument for AI within sustainable supply chain management is mostly based around efficiency improvements. Some relevant smart logistics examples from the previous section include increased demand forecasting accuracy, reduced inventory/production management redundancy, and improved supply chain network designs. All potentially achievable through AI, they directly decrease pressure on the environment *in addition to* its operational advantages.

Improved forecasts reduce waste in two important ways: by reducing the amount of safety inventory required to account for uncertainty and by reducing secondary flows and waste stemming from returns and obsolete stocks. Moreover, given that demand of perishable items is notoriously difficult to forecast, and given that AI has shown promise in the area, there is an argument to be made for the potential environmental impact of AI models for demand forecasting—and by extension, inventory management—of perishable goods.

The use of control towers to combine geographically compatible shipments, either by bundling thereof or through effective backhauling, relieves the carbon footprint of logistics distribution systems. The main reason being that improving the load factor, through bundling or effective backhauling, reduces the number of vehicles on the roads. Fewer vehicles, in turn, means lower emissions of harmful greenhouse gases, less congestion, and fewer chances of accidents. Collaborative shipping, where shipments from different companies are bundled, also facilitates the shift to greener transport modes, such as rail or inland waterways, thanks to the economies of scale that may be achieved as a result.

The potential of AI to solve complex optimization problems also plays a role in sustainable supply chain network design. Thanks to the availability of (almost) real-time data and powerful computing capabilities—in other words, thanks to smart logistics, networks with more efficient distribution routes are potentially achievable through AI. Current estimates attribute roughly one-quarter of global greenhouse gas emissions to transportation—thus, any improvement in transportation efficiency has a direct positive environmental impact. Once more, as enabler of smart distribution networks, AI shows environmental, in addition to operational, potential.

AI can also be used for sustainable supplier auditing and selection. Large, global firms typically struggle to achieve visibility across their entire supply chain. In addition, modern supply chains simply involve too many partners to allow for fruitful "manual" auditing efforts.[8] Data analytics now enable access to massive amounts of data regarding multiple sustainability dimensions of a company's suppliers, their suppliers' suppliers, and so on. Massive amounts of data, however, are challenging to process efficiently. Thus, leading suppliers in the environmental quality management space, such as EcoVadis and Intelex, have recently started to offer AI solutions as a way to generate actionable insights, such as supplier selection and development based on sustainable development standards, from these massive data sets.

All this said, the application of AI for sustainable supply chain goals is still in its infancy. One of the main challenges for the adoption of sustainable AI models within the industry is their dependence on being complementary to operational gains. In other words, it is difficult to imagine (barring government intervention) firms adopting sustainable solutions which do not simultaneously improve their operational efficiency. Thus, sustainability runs the risk of being reduced to a positive side-effect of AI implementations, instead of a primary objective in itself.

This fact coupled with the speed of adoption of AI on the consumer-facing side (e.g., in marketing and revenue management) has prompted some warnings (Dauvergne, 2020). One fear is that, even if the adoption of AI within supply chain management results in reduced environmental impact at the unit level, the adoption of AI in other areas (e.g., marketing) may, at the same time, stimulate consumption to such an extent that the combined effect is negligible or even

[8] Ford Motor Company, for example, has over 10 tiers of suppliers; the number of suppliers in their first tier alone exceeds 1000 (Simchi-Levi et al., 2015).

negative. This is not unlike Jevon's paradox[9]: sustainability through efficiency gains runs the risk of being undone by the sheer increase in consumption.

In addition, widespread adoption of AI and the subsequent requirements for computing equipment places significant stress on the demand for rare earth metals and other raw materials required to power the (significant) additional computing resources. In effect, the increased efficiency at the production and distribution sides of supply chains may be offset by an increase in environmental pressure at the resource extraction side. This relationship is particularly important given the reliance on developing and/or poorly regulated countries for extraction of the required resources. In summary, AI as a tool shows promise to bring about efficiency in logistics and supply chain management, to the extent that these improved efficiencies translate into a decrease in environmental pressure for the firms adopting AI. However, environmental systems need to be analyzed from a global perspective. Thus, looking forward, it is important for firms to be aware of the environmental impact of their entire supply chain and not only of their local logistics processes.

4 Toward Autonomous Supply Chains?

The digitization of workflows, including their work instructions, may also enable the automation of certain tasks, allowing the work to be performed by a machine instead of a human. With new digital tools providing visibility into real-time supply chain data and sophisticated algorithms capable of processing these data to prescribe decision making, some even argue that the supply chain function is rapidly growing obsolete (Lyall et al., 2018).

We believe that human planners will *not* become obsolete, although their job content may likely change in light of the technological evolution. Indeed, one should draw a distinction between automation and autonomy. Automation implies that the task is performed "without thinking," i.e., by a machine (robot) or software application (bot). Autonomy, however, means that the task is capable of operating "without external intervention," i.e., using its own control rules. In office environments, the automation of tasks is referred to as *robotic process automation (RPA)*. RPA is a software application (or bot) that performs automated tasks. By interacting with applications similar to how a human would, software bots can open e-mail attachments, complete electronic forms, record and re-key data, and perform various other tasks that mimic human action. RPA is particularly efficient in automating very specific, highly repetitive tasks that follow predefined rules. When RPA bots run autonomously (unattended), their workflows should be preprogrammed such that human involvement is not required in the processes that they perform. In order to

[9] The observation that improvements in efficiency are often associated with increased resource utilization due to an increase in total demand. William Stanley Jevon originally observed this effect with regard to the consumption of fuel in his 1865 book, "The Coal Question."

work independently, these bots follow a rules-based process to completion. Such a process is only possible for relatively simple tasks.

Complex logistics tasks arising from judgmental decisions which require context awareness (and perhaps even qualitative factors), however, are much less amenable to explicit if–then instructions used in automating repetitive, predefined tasks. For such more complex tasks, RPA bots currently run in supervised (attended) mode. In such a case, human employees work side by side with the bots, which may be likened to virtual assistants providing support to an individual employee with their tasks so as to boost productivity. Employees trigger a bot and interact with it as the bot provides assistance. Attended RPA bots therefore increase the productivity of the planner by performing time-consuming repetitive tasks, while leaving the contextual and judgmental decision making to the human.

Smart control rules may gradually increase autonomy in the supply chain as data are increasingly captured through digitally connected smart systems (the aforementioned Industry 4.0). In 2019, an Uncrewed Surface Vessel (USV) journeyed from the UK to deliver oysters in Ostend, Belgium. The USV then returned to the UK with Belgian beer. In order to safely navigate what is one of the busiest shipping lanes in the world, the USV relied on input from multiple installed sensors, including sonar, radar, lidar, camera, IR camera, and GPS. According to the USV's owner, the trip was the first commercial crossing of the North Sea by an autonomous vessel. Throughout the trip, an operator was able to remotely access video footage, thermal imaging, and radar transmitted by the USV, along with audio transmissions of the USV's surroundings. The operator was even able to communicate with other vessels in the USV's vicinity (Amos, 2019). Although the presence of multiple data sources is instrumental to increase the level of autonomy afforded to an AI system, the end result is still "supervised" automation. In order to realize full autonomous automation, algorithms will increase in complexity and sophistication (in addition to standard if–then–else rules), similar to Tesla's pursuits of incorporating state-of-the-art machine learning technology into their vehicle operating systems.

5 The Human Aspect (Going Forward)

The previous sections have demonstrated how AI is shaping a future where well-defined tasks are automated and how algorithms can solve problems that may be too complex for humans to analyze. These uses of AI raise the question *what is the role that we—as humans—are going to play in all this?* Looking back, technological revolutions have changed our ways of life in profound ways. We settled down during the agricultural revolution, we moved in large numbers to bigger cities during the industrial revolution, and we unlocked the key for real-time worldwide communication during the digital revolution. Looking forward, will Industry 4.0 bring about a change of the same order of magnitude? If AI and real-time connectivity are indeed driving us toward a fourth industrial revolution, the consequences could be far-fetching and difficult to predict.[10] One could also argue, however, that AI is integral to an ongoing evolution in the way we conduct business, such that resulting changes will be gradual and organizations will—to a certain extent—be able to anticipate them. There is a fundamental difference in the human–machine interaction within the new AI paradigm, compared to the "old" decision support systems of the past few decades. Thus far, computers have been solving models explicitly developed by researchers for a particular problem at hand. Most of these models are theory-based, relying on assumptions about causality and on abstractions about how the physical world behaves. For example, a decision support system that calculates when and how to order from suppliers requires the modeling of a demand structure and calculating the optimal trade-off in terms of the cost of having too much inventory on hand as opposed to too little. In addition to their practical implementations, the underlying theoretical models also allow us to extract insights and thus learn about the intuition behind the system being modeled. Extracting such intuition is the reason why these models are taught in supply chain education programs; they allow students to build-up their own intuition and learn how to interpret results and, eventually, how to derive their own solution methods for specific problems at hand. Such a skill set is valuable even when the problems faced are much more complex than the stylized versions seen in class.

AI in general and machine learning in particular do not require such models. Machine learning models are atheoretical and thus typically provide a prediction without requiring prior knowledge (or explicit model) regarding the problem nor additional insights or information from the user. Machine learning models are seen as a black box, because it is usually not possible to understand how they arrive at a solution/prediction. Thus, while humans are typically in full control at all stages in "legacy" decision support systems, our role within future AI decision support systems will be limited to ensuring availability of any data required by the computer to run its model and, eventually, to fine-tune the necessary reward functions and parameters.

AI is likely to bring about a reconfiguration of the core competencies of firms and, consequently, also a reconfiguration of jobs (Agrawal et al., 2018). In this view, a rethinking of the core competencies of jobs and firms is in order. Should machines take over prediction jobs, such as demand forecasting, the boundaries of a supply chain analyst's job will change: Such a professional will go from creating and maintaining forecasts to possibly just approving and archiving them. Taking this thinking to a company level, once processes are automated and do not require in-house expertise, they can potentially be outsourced. In effect, Amazon is already offering ready-to-go solutions for processes that are still commonly considered core competences of supply chain management, such as forecasting and predictive maintenance. It is not difficult to imagine a future where sales forecasts are computed

[10] Who could have predicted the loss of importance of good handwriting in an educated person 100 years ago? Or the loss of the importance of a computer user understanding the concept of manually saving a local copy of a file even 10 years ago?

by an outsourced specialized firm making use of the latest machine learning models run on state-of-the-art server farms and are received every morning.

When day-to-day requirements change, the composition of the workforce and their skill requirements will also change. With routine prediction and data processing tasks being taken over by machines, organizations will most likely demand workers specialized in analyzing computer output as well as workers with "soft" interpersonal skills, necessary for sales, consulting, and coaching functions (Ernst et al., 2019).

For workers, new tasks will emerge that may require a different combination of skills. As AI serves up improved and cheaper predictions, there is a need to clearly think about and determine how best to develop and use those predictions. Agrawal et al. (2018) refer to the job of determining how algorithmic predictions are evaluated as "reward function engineering." A reward function engineer will determine the way in which the predictions are evaluated and consequently adapted or adopted. Successfully performing reward function engineering requires an understanding of the needs of the organization and the capabilities of the algorithm. This understanding requirement also extends to management. Managers will require basic AI-literacy—knowing what an AI system can and cannot do, and knowing what their strong and weak points are. No coding necessary. Indeed, in the same way in which no coding knowledge is required to interact with a spreadsheet, no coding or knowledge of the underlying technology will be needed to interact with and supervise AI models. With widespread adoption, and thanks to the abovementioned availability of open-source resources, coding/development of machine learning frameworks may be completely dissociated from its application.

Even if a firm outsources certain supply chain processes to machines, an analyst will still be required to interpret AI output and to sign-off on decisions. For all the advantages AI has over human decision making in terms of data processing, humans still trounce AI in the nuances of understanding context and qualitative information. A human decision maker can navigate new situations through context clues; AI is typically as good as its training data. Things that are still easy for a human to spot are not possible for an AI system if not explicitly trained. For example, in 2018, Reuters reported that Amazon had to abandon an AI recruiting tool—capable of grading job candidates based on their resumes—because it discriminated against women. The AI model had been trained with resumes from previous applicants, which skewed heavily male. The machine learned the implicit biases in the recruitment practices, and female traits were seen as negative by the system.

It follows that, in outsourcing/automating predictions and recommendations to AI algorithms, the role of humans will necessarily move toward that of being gatekeepers. Even though it is still early days in the adoption of AI in the corporate world, Acemoglu et al. (2020) recently performed an empirical study using vacancy data from 2010–2018. They found that (1) AI-related jobs increased steeply after 2014, (2) there was evidence of job replacement with AI-jobs replacing other, now-automated, jobs, and (3) there is no effect (yet) of AI on the aggregate level of employment.

In light of all this evolution, one thing has become clear: Data and data management will become increasingly important. Whereas, historically, data has been siloed within a company, where each decision maker compiles and stores their data independently, we foresee—especially in applications where data is a competitive advantage—the adoption of a "data manager" or chief data officer (CDO) with an overview over all the data retrieval and storage processes in a company.

Finally, we note that, despite its many productivity improvements, the widespread adoption of AI in the workplace does not come without its risks. Ernst et al. (2019) performed a detailed analysis of the implications of AI on the future of work. Even though their conclusions are optimistic, they note that certain challenges will require smart policy making and conscientious adoption of the technology. From a supply chain perspective, they warn about an increase in inequality due to the automation of operational tasks. Of particular concern is the impact of AI in developing countries. Increased use of capital-intensive technologies can increase inequality in countries with large percentages of under-utilized, under-educated labor. In contrast to the agricultural revolution, in which automation in agriculture led workers towards low-skilled jobs in manufacturing and eventually to increased income and education, during the current industrial (digital) evolution manual jobs are being increasingly replaced by higher-skilled jobs in service, design, and supporting roles. The move to AI adoption and automation contributes to these trends. The main fear is inequality in job creation, where mid-level jobs are replaced by low-end and high-end ones. To the extent that highly educated people are better at learning new skills, and the skills to succeed with AI will change over time, then the educated managers will benefit disproportionately.

Management Perspective on Data, Data, Data[11]

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Atlas Copco is a Swedish multinational industrial company that manufactures industrial tools and equipment. In 2019, global revenues totaled SEK 104 billion (approx. e10 billion) and by the end of that year the company employed nearly 40,000 people. Atlas Copco companies develop, manufacture, service, and rent industrial tools, air compressors (of which it is the world's leading producer), construction, and assembly systems. Atlas Copco is global market leader in most of its segments. It manufactures critical equipment components in-house and co-operates with business partners for non-critical components. Atlas Copco co-engineers and buys a lot of parts and only produces core components in house. A main contribution of the revenues is generated from

(continued)

[11] "Data! Data! Data! I can't make bricks without clay." Sherlock Holmes, *The Adventure of the Copper Beeches.*

service (spare and consumables, maintenance and repairs, uptime contracts, air as a service, accessories, rental). Service is the responsibility of divisions in each business area. Atlas Copco is worldwide represented and has own customer centers in about 71 countries.

As an engineering company, Atlas Copco has always embraced innovation and new technologies to continuously improve its products and processes. The company is also leading when it comes to sustainability goals and limited impact on environment. To date, more than 170 K of our installed compressors worldwide are connected through Internet of things technologies, sending information about their operating condition. This can vary between every minute and weekly information. This massive amount of data is processed through cloud computing to guarantee uptime, machine efficiency and lowest total cost of ownership for the customer. Well-timed preventive maintenance interventions avoid costly machine downtime and prevent machine components from being replaced too early. At the same time, the lowest energy consumption for the customer can be guaranteed.

Accurate prediction of maintenance interventions is also instrumental to have the right spare parts in stock at the right place at the moment when they are needed. The use of *big* data in logistics goes a step further than the IoT application for preventive maintenance. As a machine state is directly linked to sensors, an accuracy of 98% on AI algorithms for machine failures brings substantial benefits on boosting the up-time further beyond the normal conditions. In logistics, however, 98% of the demanded stock keeping units are "relatively" easy to forecast; the complexity is in predicting the remaining 2% of the (very) slow-moving products. Unfortunately, those products are only rarely used, and thus also only few data points are generated. It thus turns out that for those stock keeping units where accurate data would add most value, only *small* data are available.

Digital solutions also support Atlas Copco's transport operations. Containers shipped by boat or truck are equipped with sensors to track and trace incoming products throughout their journey using digital control towers. Multiple insights are provided by the transparency that comes from knowing when the container has left its origin, when it encounters a delay, and when it is planned to arrive on site. It can for instance lead to emergency air shipments if the component is highly urgent or it can suggest replanning the production line based on the expected arrival time of the missing components. When the part is intended for customers or for own service engineers, they can be timely informed about the status of arrival. Finally, by analyzing historical trajectory data, one can learn that—or when—some trajectories take longer than planned, such that the corresponding replenishment parameters may be updated. Although the transport control tower is today still its infancy, it is a growing opportunity area.

(continued)

There is also opportunity to optimize picking locations in the warehouse by analyzing historical orders. By grouping products that are frequently purchased together in each other's vicinity, picking productivity can be enhanced. The same analysis can be instrumental to optimize service levels per order line, depending on the combination of products that are often included in the same order.

All these opportunities, however, stand or fall by the accuracy of the data. Bad data results in poor quality decision making, which makes any attempt to adopt AI moot (*garbage in, garbage out*). The quality of the master data is important in order for it be useful. This makes a strong case of integrated data systems.

Data and analytics have always been important at Atlas Copco. To leverage the true benefits of AI, data scientists are connected to the business. Logistics and supply chain executives do not necessarily need to be computer scientists, but they do require an analytical mindset and a data science acumen to understand how AI can bring value to their profession. And most importantly, they need to be critical on the data and—together with the data science team—co-own responsibility on data quality.

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How to Design Human–Machine Interaction in Next-Generation Supply Chain Planning

Kai Hoberg and Christina Imdahl

1 Introduction

When asked about the frequent delays and missed deadlines for the various Tesla models, Elon Musk in a panel discussion on June 2, 2016, highlights all of his challenges dealing with suppliers, manufacturing, and logistics from "burnt down factories" to "shootouts at the Mexican border." He concludes that "the supply chain stuff is really tricky".[1] While this complexity might have been a new experience for the (currently) world's richest man, it is common knowledge in the supply chain management community. In particular, the quality of supply chain planning directly affects the operational performance of many firms. It compromises all planning activities from manufacturing and distribution network design on a strategic level to demand forecasting, production scheduling, or inventory management on an operation level. As a consequence, more than half of all supply chain jobs are directly planning-related (Sodhi et al., 2008).

Let us have a closer look at why supply chain planning matters based on the example of a classic brick-and-mortar grocery retailer (e.g., Kroger, Carrefour, or Coles). With superior demand planning, the retailer can better predict daily sales in her stores and order goods in advance to handle demand peaks and avoid stock-outs. With improved inventory planning, the retailer can reduce overstocks, markdowns, and food waste. With better scheduling, trucks reduce carbon emissions, avoid traffic

[1] See the video here https://www.youtube.com/watch?v=wsixsRI-Sz4#t=1h11m50s at 1 hour 11 minutes 50 seconds.

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jams, and arrive timely at the ramp when the store personnel are available to store away the goods into the shelves. For every industry, there is a myriad of examples that similarly highlight the importance of better supply chain planning. And ultimately, better planning results in higher customer service, higher sustainability, and lower cost.

Over the course of this decade, numerous changes will affect supply chain planning. Many of these can be traced back to developments that have already been observed in recent years. On the one side, there is an increasing need for superior planning solutions: Customers are more demanding in terms of shorter lead time and on-time order fulfillment, buffer capacities and inventories are reduced to deal with increased cost pressures, and the broadening product portfolio and multi-stage material flows are making planning more complex. As a result, the number of decisions required in planning is growing rapidly: Decisions are made more frequently (e.g., multiple times per day instead of weekly), on a more granular level (e.g., for each article instead of the product category), and are required for more stages (e.g., multiple production plants rather than one). We refer to this as the supply chain decision explosion.

On the other side, there is new technology available that promises to improve supply chain planning processes. Big data are becoming available and offer the opportunity to enhance the standard ERP data that are currently the basis of most supply chain planning (Alicke et al., 2019). Untapped data sources include information that is collected by supply chain partners (e.g., GPS sensors, RFID scans, cameras, wearables, and point-of-sale information) or information that is collected for other purposes (e.g., commodity prices, weather forecasts, traffic information, Internet, or social media data). Technologies such as cloud storage and new software platforms offer ways to handle these data. However, the most crucial step is to obtain insights from the data to make it actionable and derive decisions that can improve supply chain planning.

Here, artificial intelligence (AI) and machine learning (ML) offer a huge potential over traditional methodologies since they can deal with greater complexities. For example, in demand forecasting, traditional approaches are built around time-series analysis that aims to capture the evolving demand over time considering trends and seasonality (e.g., using triple exponential smoothing or Box–Jenkins models). Based on past observations, trends are extrapolated into the future and potentially adjusted by the average effects of promotions (e.g., obtained from a linear regression) or a few other important exogenous variables. However, with ML approaches it is possible to jointly consider the effects of hundreds of different variables in order to create much deeper insights into the mechanisms that are driving the demand. For example, the effect of good weather on BBQ products for a Saturday during the summer for stores in suburbs might be very different from the effect of good weather on cosmetic products in the winter for stores in a holiday region. All different factors can be considered in parallel using advanced ML approaches like deep learning or support vector machines. Accordingly, the individual forecast model for the different cases will differ widely. Based on the computing power available today, these forecasts can now be made for tens of thousands of stock-keeping units (SKUs) at hundreds of stores and for multiple weeks in advance, resulting in more hundreds of million demand forecasts per day at a single retailer (Khosrowabadi et al., 2021).

However, this huge complexity creates multiple dilemmas for the planners in charge of all supply chain decision-making that will fundamentally affect their role in the future (Alicke et al., 2019). This is a particular challenge as humans are known to be imperfect decision-makers (Hoberg et al., 2020). As a result, several key questions need to be answered for the future: How to design AI systems that efficiently handle the huge number of potential decisions? How to fine-tune and test the algorithms that create the decisions? How to understand the decisions that were created by AI? When to intervene with the decisions created by the AI and when to let go? Will human planners be removed from decisions and focus on meaningful and more creative tasks? Certainly, these are just some of the challenges that must be addressed over the course of this decade. As such, it will be important to enable a fruitful collaboration between the planning system ("the machine") and the planner ("the human"), which we refer to as human–machine interaction. This successful human–machine interaction is particularly important as planners will remain an integral part of the supply chain decision-making processes for the foreseeable future in many firms.

Against this background, the objective of this chapter is threesome: First, we outline how next-generation supply chain decision-making will evolve along with higher levels of automation and highlight why no-touch or lights-out planning will not become a reality anytime soon in most companies.[2] Second, we aim to highlight the enablers of a successful human–machine interaction. Given the many hindering factors like human biases, change resistance, or accountability, it is particularly important to raise the confidence of the planner in the system. We highlight the required paradigm shift from "the planner decides at every moment of truth" toward "the planner improves the system and handles exceptions as needed." Finally, we provide guidance to supply chain talents on how to position themselves along this journey and outline skill sets they need as it is critical for them to develop. This is particularly relevant since roles and job profiles in supply chain management will become more differentiated in the future.

2 Next-Generation Supply Chain Decision-Making

2.1 The Advancement of Machine Systems

As highlighted before, digitization of decision-making is advancing rapidly, in our everyday lives and in supply chain management. We rely on navigation advice from our phones and recommendations from Netflix for the movie program. Similarly, traditional systems for supply chain decision-making are overhauled by more and

[2] See the controversial article on the death of supply chain management to see a different perspective. CITE: https://hbr.org/2018/06/the-death-of-supply-chain-management

more advanced systems that leverage all types of data to enable better decisions. Data exchange and sharing have become fast and reliable through employing technology such as electronic data interchange (EDI) or cloud-based systems that make large amounts of data accessible for many agents. It is a major improvement to leverage all types of data, from weather forecasts (Steinker et al., 2017) to social media data (Cui et al., 2018) for supply chain decision-making. However, this has also increased the complexity that comes along with these systems. Processing data from different sources require the right infrastructure, the right people skills, and the implementation of sufficient quality controls.

In a supply chain context, a certain degree of automation has long been common standard in traditional systems. For example, forecasting using statistical methodologies or inventory planning with re-order point policies has been embedded in most standard ERP and advanced planning and scheduling systems for decades. With the increasing availability and affordability of computational power, more sophisticated analytical tools are being deployed. Leveraging advanced machines and algorithms is compelling for many reasons. The machines can make many decisions with almost no latency, which is important for situations where live decision-making is necessary, for example, in transport management or in inventory pricing. For example, UPS has deployed its meta-heuristic-based ORION system to optimize real-time routing for UPS' 55,000 US drivers with expected savings of US$300–400 million annually (Holland et al., 2017). Amazon has been automating many activities in its retail team such as forecasting demand, ordering goods, and also negotiating prices with its suppliers (Soper, 2018).

Some more advanced AI methods also have the ability to learn by themselves, in that way adapting to new situations and making decisions completely autonomously (Boute & van Mieghem, 2019). However, still little is known on how AI algorithms learn, and what is included in their decision-making. Often, the AI tool remains a black box for decision-makers and managers, making it undesirable to rely on machine-only solutions. Hence, the decision-maker is and will continue to be part of the decision-making process for the foreseeable future in most companies.

2.2 The Role of the Humans

Thus far, automation with computerized systems mainly targets regular routine work (e.g., statistical forecast generation and applying MRP logic for orders). In many systems, the algorithms provide first guidance for the decisions, but the ultimate decision is made by a knowledgeable human interventor that oversees the recommendation and adapts it, if necessary. Employing both, humans and machines, can combine the benefits of both worlds. The machine provides rational decisions based on cost and data analysis for a huge number of decisions, while the humans enable tacit knowledge, fast reactions, improvisation for unattained events, and human (ethical) judgment. This human contribution to the decision can still be extremely valuable for many reasons: (i) Machines do not have access to all types of accurate, real-time data due to data quality problems, time lags, and the challenges accessing

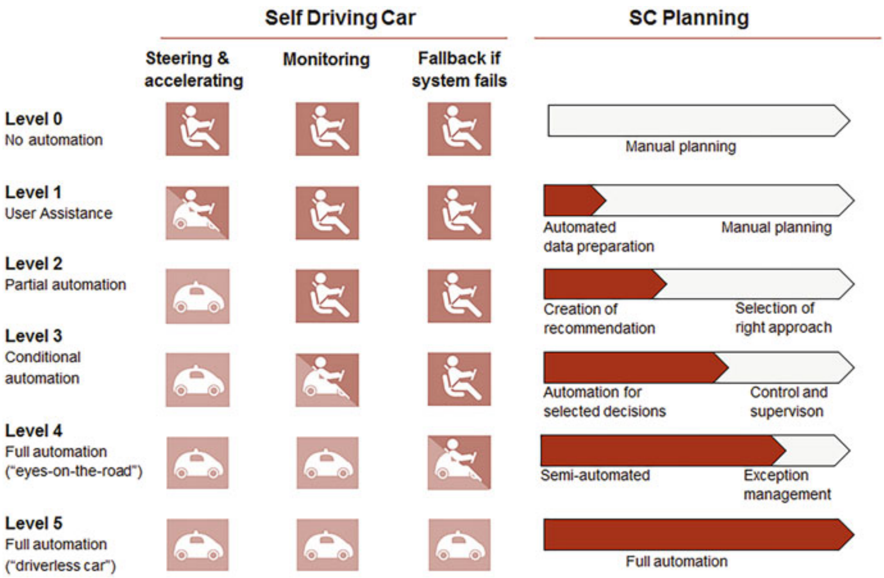


Fig. 1 User perspective on automation in self-driving cars and supply chain planning

certain types of data. (ii) Machines train on past data that may not be representative of the current situation (data shift). Certain triggers such as the COVID-19 pandemic, the Suez channel blockage, or border closures have not been observed before, and their effects on customers and the supply chain have been difficult to anticipate. (iii) A decision might be too complex and too important to be made by a machine. Decisions on the allocation of critical goods such as during the shortage of ventilators or oxygen in the COVID-19 pandemic or microchips in 2021 are multidimensional and also involve ethical judgment. In those situations, humans can better identify the underlying problem and account for influential factors ignored by the machine.

The humans may interact with the system at different degrees.[3] The design of the interaction determines how many, which, and to what extent a human decision-maker may adjust machine recommendation. The amount of human oversight in supply chain planning processes can be well compared to the evolution of self-driving cars (see Fig. 1). Traditionally, all cars were completely driven by humans (Level 0). Then, navigation systems came along assisting with navigation (Level 1) and cruise control automatically adjusts and keeps the speed (Level 2). These systems have advanced, and automatic parking assistance can, under certain conditions, overtake the parking task completely (Level 3). Teslas were then the first cars to be driven autonomously with human oversight on highways (Level 4). In

[3] Also, humans and machine can interact in very different ways—see Shrestha et al. (2019) for an interesting discussion on the sequence of the interaction.

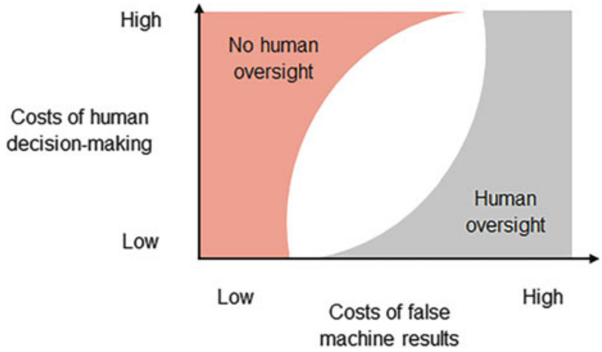
Level 5, the fully automated stage, no human oversight will be necessary anymore. The vision for autonomous driving without any guidance is already clear but not yet implemented.

For supply chain planning, the user assistance on Level 1 has commonly been implemented, for example, in the form of an automated data preparation that pulls information from different databases and thus helps the planner to compute her decision. On Level 2, recommendations are based on a more simplistic (or sometimes already more advanced) methodology. A common example is the generation of replenishment decisions based on the standard MRP logic. Considering data such as future production plans, upcoming deliveries, batch sizes, and lead times the planning system recommends the planner when to trigger an order at the supplier (Orlicky, 1974; Van Donselaar et al., 2010). However, the planner is in charge and ultimately decides when to place the order. On Level 3, this approach is already partially automated (e.g., ordering for low-value items or items with regular demand). On this level, the user trusts the system to a certain degree but feels that more control is necessary for other decisions (e.g., ordering more expensive items or parts from suppliers with volatile delivery performance). While these automation levels are already quite common in many companies, Level 4 reverses the responsibility logic and puts the machine fully into the driver seat. Here, day-to-day decision-making is semi-automated and the planner is only required for exception management. In order to train the system about the reasons for exceptions made, they must be documented (and approved by supervisors), which leads the path toward Level 5, where decisions are fully automated.

For traditional systems, or "white-box approaches," the role of the human decision-maker is mainly to account for factors that are not included in the system. In a retail sales forecasting context, these may be promotions, unusual weather, or competitor actions. Those factors are often not included in the system due to a lack of reliable data sources, complexity in integrating information, or a disability of the utilized system to account for all potentially relevant factors. Due to the static nature of the traditional systems, it is unlikely that automation Level 4 and Level 5 of automation with "human-out of the loop" are soon widely employed within these systems. Level 3, conditional automation, may be leveraged with smart algorithms on-top of the traditional systems that identify respective conditions for automation (see, e.g., Imdahl et al., 2021).

However, new AI-based systems may take new information into account and adapt the factors that they base their decision on dynamically. The black box approach though makes it hard to understand, which information has been included in the recommendation; thus, humans cannot easily obtain insights on the quality of the proposed decisions. Similar to the car analogy, the main question when employing computerized systems is how much control one is willing to surrender and where human oversight is actually necessary. This will highly depend on the risk associated with a false machine recommendation. If by giving up steering control the decision-maker may risk his life with a car crash, he is less likely to do so as opposed to a situation in which he gives up navigation control and only risks a longer route. Decision-makers need to trade-off the costs of employing human oversight with the

Fig. 2 Trade-off applying human oversight



incremental cost of a false decision of the algorithm (see Fig. 2). In one extreme, if costs of a false decision are high, human oversight should be employed to limit the probability of a false result (gray zone). For example, in healthcare AI systems are employed to detect cancer, or predict drug interactions and costs of a wrong prediction may be tremendous. On the other hand, if costs of a wrong result are negligible, the likelihood of a false result is small, or the human decision is also very error-prone, and human oversight shall be limited (red zone). Human skills shall not be underutilized on such tasks in line with lean management.[4] In addition to these two points, firms implementing human-and-machine systems will need to consider the investment costs to set up a sophisticated machine system and the quality of that can be obtained by the machine. Depending on the tasks, there may be huge differences in the value-adding ability of the humans (and the machine). We talk more about the design of such systems in Sect. 3.3.

For many applications, this means that the role of planners will change. Freeing up the time spent on no or low-value adding activities will result in more time available for strategic and creativity-based tasks, like process improvements or communication that cannot be replaced by machines. From a lean perspective, this leads to a reduction in human skills wasted. However, for most companies, it will be an evolution that requires time and experimentation and the tasks might be shifted to different roles.

[4] Amazon, for example, with the increasing maturity of its "Hand-of-the-Wheel" program and growing reliability of machine decisions, has shifted employees from its retail operations to other units (Soper, 2018).

3 Challenges and Enablers in Human–Machine Interaction

3.1 Culture Change

In many firms, supply chain management is not seen as a value-driving function but rather as a cost center (Hoberg et al., 2015). Most attention is received if something goes wrong; e.g., deliveries are late, stock-outs occur or customers complain. Accordingly, there has always been an inherent pressure for planners to avoid these disruptions to happen. Faced with poor data quality and legacy systems, planners have often developed a preference to take decisions manually to be in charge at the moment of truth.

However, with automated systems, this culture will need to change. On the *operational level*, automation will lead to a perceived loss of control as planners will not be able to make every decision by themselves or can check every individual system recommendation. Given the black box features of advanced systems, planners might not easily understand the decisions proposed. Anyhow, planners must relinquish control to enable automation. Both planners and the entire organization need to build trust and tolerance into the system as late deliveries and stock-outs will continue to occur (at lower rates). To enable this transition, a timely feedback mechanism that informs planners of the decision quality and highlights potential problem areas is crucial. In addition, systems must have the capability to provide explanations for the decisions and recommendations made. For example, a forecasting system can provide information about the features driving a particularly high or low demand value.

On the *strategic level*, planners must remain accountable for decisions made by automated systems as management will not accept the excuse "the system made the wrong decision." They need to continuously understand all aspects of the decision-making process beginning at the input data that are fed into the system to the performance impact of certain algorithm choices. However, the planners' focus needs to shift toward the optimization of the automation systems. They will spend more time on improving algorithms, fine-tuning parameters, and ensuring data quality to boost the system performance rather than trying to avoid individual mistakes. To enable this shift, the incentive system of planners will need to be extended. Instead of focusing only on traditional SC performance metrics such as forecasting accuracy or on-time-in-full performance, incentives need to also include value-adding automation performance metrics, e.g., the number of forecasts that were completed autonomously or the number of exceptions that need to be handled manually.

3.2 Operational Level: Trust and Explainability

An important challenge when dealing with advanced AI systems is user acceptance. As human decision-makers deal with AI advice, they exhibit algorithm aversion (Dietvorst et al., 2015), overconfidence in their own decisions (Gino & Moore, 2007), and generally discount advice. This is particularly challenging as most AI methods are lacking information on which inputs are employed and how these inputs are processed to generate decisions or recommendations. This may be frustrating for planners interacting with those systems, especially in case of errors and wrong decisions. It is often hard to assess and understand, whether a decision that has led to a negative outcome was due to stochasticity (e.g., it was just a day with randomly low demand) or due to an unreasonable aggregation of decision parameters (e.g., the combination of product, day of week, and weather was not considered correctly). In that case, the planner might not know whether future decisions are prone to the same mistake. In fact, this may even lead to a "double accounting" of effects, where the machine and the human learn to account (or not to account) for certain factors. For example, we talked to the chief data scientist of a leading retail analytic provider who highlights a common challenge: the planners of a retailer observed that the AI-generated forecast was under-forecasting demand for the Christmas peak season—accordingly in the next year they increased the demand forecasts to compensate for the perceived too-low forecast. However, the AI system had already learned the error and increased the forecasts, which were now overcompensated by the planner's intervention.

Building trust into the decision-making tool by making its decisions (at least partially) interpretable is crucial to avoid planners rejecting the advice or drawing incorrect conclusions from past decisions. Two components will be critical in training planners to use the new methodologies: explaining the decision of the algorithm and giving feedback on the planner's decision. Many software providers are already working on the first by providing marginal analysis (counterfactual results should one parameter change) or by providing rankings of parameter's importance (see Fig. 3). This way, planners know which factors have been accounted for and get an intuition on the sensitivity of the decision. In Fig. 3, the planner first identifies that the discount is the most important feature driving the demand (with 43% importance). Then, he can observe the sales (red line) and past discount (gray bars) in the previous weeks. Based on this is, he is also able to understand the peaks in the demand forecast (dotted red line) that are in periods with planned discounts.

Proving feedback to planners will also be important to avoid future errors. Here, it is crucial to identify the right type of feedback with the right level of aggregation at the right frequency. More frequent feedback can focus user attention on random noise in recent observations (Lurie & Swaminathan, 2009) while increasing time delay between the decision and realization (and feedback) deteriorates performance (Diehl & Sterman, 1995). Design feedback systems based on the right trade-offs will become crucial to the success of self-service decision-making.

3.3 Strategic Level: Design and Control

Transitioning to more automated systems requires the planner to let go of control and to accept that there are situations in which they may not influence the final decision. Humans in general do not like that lack of control. In fact, humans tend to use advice

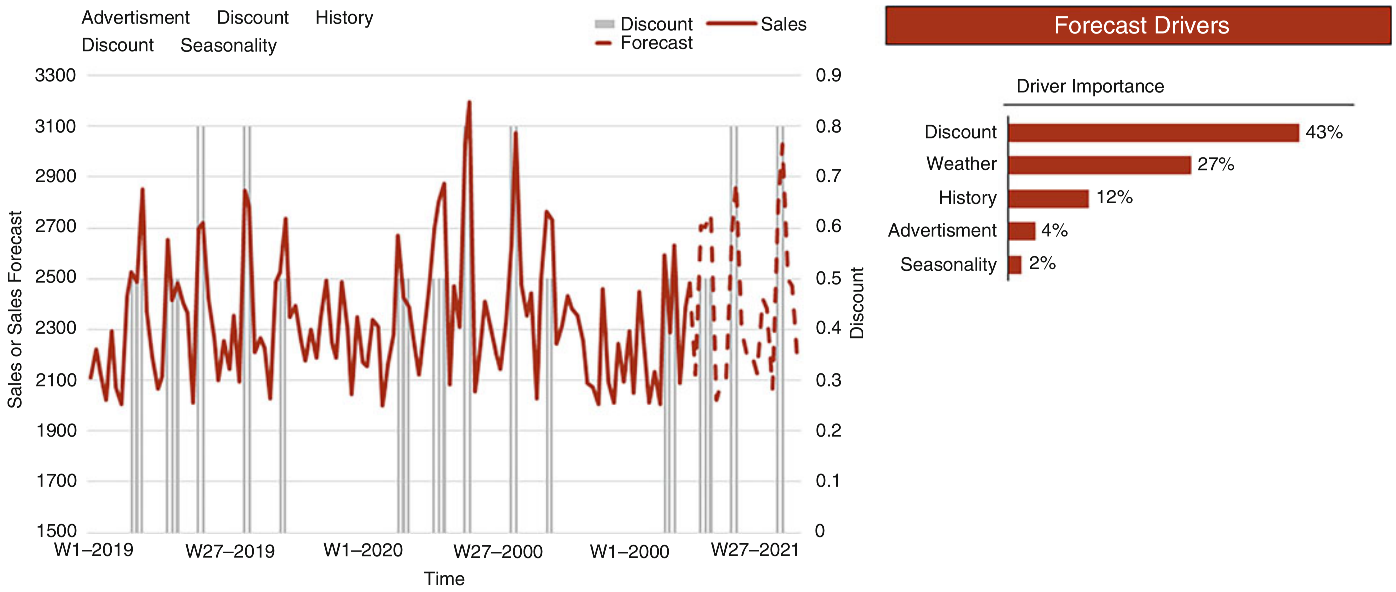


Fig. 3 Example of a user interface providing intuition on the algorithm's predictions

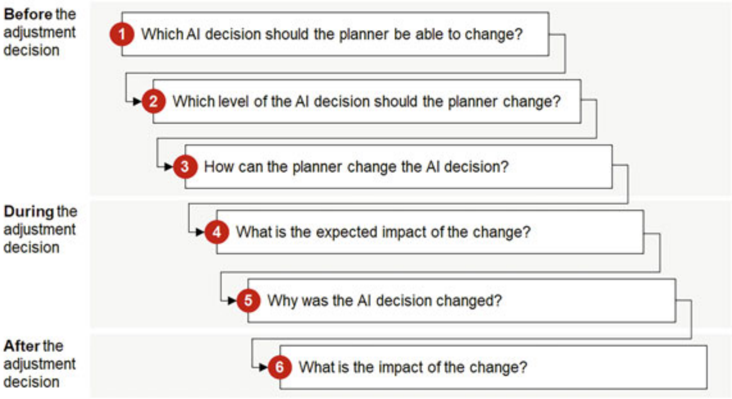


Fig. 4 Six-stage framework on the design and evaluation of human–machine interaction

more, if one allows for adjustment, even if they are small (Dietvorst et al., 2018). For a system to work well in practice, it must well attain to the different interests of the decision-makers. When designing the system, it is important to carefully consider the user to drive its acceptance and adoption.

On a strategic level, the design of the human–machine interaction and the evaluation of decision performance must be decided. We develop a holistic six-stage framework on the design and evaluation of human–machine interaction (see Fig. 4). First, it must be decided what decisions a planner may change. For certain decisions, there may already be a history of poor human adjustments. In these cases, future adjustments should only be permitted with the supervisor's approval. It might be reasonable to limit the number of adjustments to ensure planers do not intervene too widely. From a pool of decisions, the planner may either arbitrarily decide which one she may adjust or there is a pre-selection or pre-ranking performed by algorithms (if a system already employs Level 3 to Level 5 automation capabilities). The second decision dimension refers to which decision level may be changed. Often, there is a hierarchy of decisions that must be considered. For example, an upcoming heat wave could drive the forecast for ice cream. This will then affect demand for many SKUs in many stores for multiple days. Accordingly, it must be decided for which part of the AI forecast the change should take effect and on which level the planner should place his adjustment (e.g., SKU level or product family level, store, or region). Third, it must be decided how the decision-maker may adjust the recommendation. For example, adjustments may be limited by size or direction. Van der Staak et al. (2020) suggest a choice of changes in the demand forecast (e.g., +20%) to avoid marginal changes that typically do not add value.

During the adjustment process, it is important to provide the planner with the right decision support and to gather information relevant for further evaluation of the decision. Here, the humans should be guided in the decision-making process before finalizing his decision. For example, the planner could receive information on why the AI recommendation is particularly high or low or get information on the average effect of this adjustment in the past before confirming his choice. Such a smart design may counteract human biases such as optimism, overconfidence, or anchoring bias. In the next step, it is important to understand the reason for the change. Should planners just be able to override a decision without providing a reason? This could be helpful if many changes are required. However, a reason (e.g., weather information, competitor action, and new promotion) would help the AI system to better learn for the future and would help the planner to get feedback on the overrides.

Finally, performance measures must be evaluated and clearly communicated. In the future, an AI might not span only one department, but may be connected with Ais from other departments. Together, they may work to optimize the overall performance. For the planners, it must be clear what happens in the event of a false decision and how that will be perceived by sales or manufacturing functions. In addition, the information is important to further advance the AI system. All in all, these six steps are crucial and eventually decide the effectiveness of the human interaction and involvement.

4 Implications for Supply Chain Talents

Prior research has indicated that there is neither a unique career trajectory for supply chain talents (Flöthmann & Hoberg, 2017) nor coherent hiring criteria (Flöthmann et al., 2018). Ultimately, there are very different paths into a supply chain executive position. The same might hold true for talents that aim to pursue a career in supply chain planning in the future. In the past, many planning jobs were filled with talents already familiar with the company processes and some interest in numbers. However, in more and more companies, routine jobs can disappear due to process improvement and increased automation following.

As technology advances, we will see *more specialized job profiles* around supply chain planning in the coming years. On the more tech-focused end of the spectrum, a key role will be the supply chain data scientist. She will continuously upgrade the system, advance algorithms, and improve parameters (input adjustment) to increase both the automation level and supply chain performance. She will be assisted by data engineers who are responsible for embedding flows of diverse, high-quality data streams into the planning systems. On the other more execution-focused end of the spectrum, a key role will be the exception manager. In order to deal with the still inevitable issues, exception managers need to interact with the different functions, suppliers, and customers to solve these problems (output adjustment). In this role, we will see talents that can holistically analyze challenging situations, have great communication skills, and can improvise under stress. An exception manager still needs to develop supply and demand scenarios and has to use advanced tools to identify the best possible scenarios. This role is an excellent example of the "automation paradox" (Bainbridge, 1983): as more and more simple, routine tasks are automated the remaining tasks are becoming much more complex on average. While handling some critical exceptions per month has been part of a planners' job in the past, it is a standard task for the exception manager.

With the advancement of AI systems, another key question is the *level of technical expertise* that is required for a planner to do the job. Here, we have to differentiate between users and designers. Referring back to the example of the car industry, every automotive mechanic must have a detailed understanding of the function of a steering system in order to fix it. However, the taxi driver might not need that in-depth expertise although she spends more time with the car. She only needs to understand the basic relationships. The same might hold true for some planners in the future: she does not need to understand which latest ML algorithms are applied. Rather, she needs to understand the input data used and the features that are predominantly affecting a certain decision.

A key question is to what degree *small- and mid-sized companies will be able to leverage advanced supply chain planning solutions* and to what extent planning will be commoditized. On the one hand, market leaders like Amazon or Intel are investing huge amounts into advanced AI-based tools. With thousands of highly qualified talents in just one of its tech teams, Amazon is rather far on the journey to in its "Hands-of-the-wheel" program. On the other hand, even multi-billion dollar companies struggle to get investments and required expertise for better supply chain planning tools. This seems to be an opportunity for both specialized software providers and startups and could revitalize the discussion for "supply chain (planning) as a service." In particular, as SAP APO, a standard planning tool has reached the end of life status, and many companies are now actively aiming to reshape the planning IT landscape. Here are certainly interesting job opportunities for supply chain talents. The idea to embed specific tools or data streams via marketplace solutions (similar to Apple's iTunes store) highlights also opportunities for interested entrepreneurs.

All in all, any career in supply chain management will certainly benefit from any expertise around next-generation planning tools. Practitioners and students have many opportunities to obtain them—using a broad range of options from full-time supply chain programs at universities to online classes at specialized service providers. However, the on-the-job experience will also be essential.

Management Perspective on the Future Role of Supply Chain Planners

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The role of supply chain planners is changing. It is becoming critical to master the ever-increasing complexity in supply chain planning. Technological and academic progress supports current and new supply chain planners in this. The same is true for the introduction of artificial intelligence and machine learning capabilities and the introduction of data lakes where many siloed data are

(continued)

collected. These elements will have a tremendous impact on-the-job content of the planners and therefore on the required capabilities. Below, we outline five muscles to train. Some existing but also some new capabilities are important to strengthen the planning expertise and associated business value add.

Plan–Do–Check–Act

The good old plan–do–check–act capability remains relevant. It is a key vehicle to drive a performance and continuous learning mindset and culture. To truly assess planning performance and value add, a rigorous planning value add assessment needs to be installed. This should include root cause analyses via 5x "why" method to pinpoint the main drivers of miss-performance and fuel a learning cycle to which-ever domain, for example, in pricing, promotions, one-off events, or AI/ML statistics. These learnings should be collected over a longer period to build a world-class and in-depth understanding of the true behavior of the ecosystem.

Pareto and Segmentation

Another classic and important muscle to strengthen is on Pareto- and segmentation capabilities. Whether we like it or not, we need to divide our valuable time to where it matters most. Typical ways to do that effectively are understanding and applying classical value-based ABC, volatility-based XYZ, and product life cycle stages. Add customer and go-to-market segmentation to that, and planners do have a solid set of segments. Not only to focus attention to, but also to liaison with important stakeholders like finance, sales, marketing, and product management.

Collaboration

Building on this liaison theme, more and more the planners have to be strong in collaboration. We should be able to dynamically cover "detailed events" and maintain a high-over ecosystem helicopter view. The planner should grasp and thoroughly understand all ecosystem dynamics. With the introduction of next-level AI/ML statistics, it is also critical that the planner leads the collaboration with the AI/ML experts. He should understand at the "gray box" level what is built. AI/ML experts in their turn need to avoid a silo that is formed by understanding what the planners are targeting to achieve. Together, they should have to be aware of the change management needed to use the AI/ML plan as a baseline at all, first by planner but indirect by each leadership function.

Drive Decision-Making on "One Plan"

This brings us to another capability aspect of the planner: selling the plan. How to build key scenarios includes its impact and consequences based on

(continued)

assumptions and drive leadership decision-making, especially when the "most likely" scenario does not bring us to business targets.

We believe that also the other way around is true. Not having these cross-functional collaborations and understanding in place will lead to counter-productive situations. Situations in which disbelieve will drive ignorance, frustration, and overruling of the plans to targeted "wish" levels, potential finger-pointing, and lower performance levels.

Building Trust

The above leads to yet another managerial and influential capability of the current and new SCM planner: building trust. Build trust in both processes, assumptions, underlying statistics, and outcomes will be key to driving adaptation and maturity. Resilience, stamina, and willingness to commit to this are key success factors and—to our humble opinion—a far bigger challenge than building the AI/ML muscle or other technocratic planning system.

We believe these five capabilities are key success factors moving forward. It is the job of the demand planner to combine all the diverse inputs consistently and logically: Anecdotal inputs, that are potentially biased by optimism or conservatism, both qualitative or quantitative. And if the planner succeeds in finding the perfect recipe to cook a forecast that is both realistic and defendable, pressure around targets and incentives come into play. What if the demand plan is not leading to the desired outcome? How to avoid that all the prep work is ignored? What if the planner is demoted to a clerk who should "just" upload a plan which will hit the target(s)? It is crystal clear that for a planner to be successful, the "soft" skills around influencing, collaborating, pitching, and driving decision-making in a "political" target-rich environment are key to moving forward. It requires a mindset of a marathon runner: focused, resilient, motivated, prepared, social, brave, and capable of inspiring others to run along.

In that sense, we see the SCM planners become the real orchestrators of end-to-end supply chains with the steering wheel and controls in their hands. They have direct impact on customer service levels, and thus brand perception, profit and loss, and the balance sheet.

It is a powerful position to be in. But we have to earn that position and voice at the table.

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The Circular Economy and Green Supply Chains

Joseph Sarkis

1 Introduction

Communities, governments, and organizations—for-profit, non-profit, and non-governmental (NGO)—now realize that our natural resources are limited. Planetary resource limits and environmental burdens from emissions by organizations and their supply chains have resulted in pressures for more effective environmental and resources management. This issue is a global concern.

As this global realization expands, the United Nations introduced its millennium development goals which eventually translated into the sustainable development goals (SDGs). Stakeholders, especially organizations, have started to integrate these SDGs into their strategies and policies.

In response to these various societal, economic, and environmental forces, a broad-based circular economy (CE) has been proposed to help balance economic with environmental dimensions. Green supply chain management (GSCM) has been proposed to help support CE principles. These two topics and how they are managed with opportunities and challenges form the core considerations of this chapter.

We provide some initial discussion and potential answers to the following questions:

1. What is the circular economy?
2. What is green supply chain management?
3. What are the opportunities and challenges associated with the adoption of these two broad supply chain management-related practices?
4. What skills are required by logistics and supply chain managers to successfully navigate these challenges of the 2020s?

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Each of these questions will be addressed in turn over the next four sections of this chapter.

2 The Circular Economy

A circular economy has recently gained greater importance, but the basic practices and ideas have existed for well over a century. In modern economics, the term gained interest as chapter in a book by Pearce and Turner (1990). Even before that period discussion of closed cycles for manufacturing and industry were discussed ranging from simple recycling to more advanced reclamation processes such as remanufacturing. The goal has been to extend the life of materials and products.

These early periods of scholarly and practical development of circular economy principles evolved from the environmental evolution occurring from a post-World War II economy based on mass production and consumerism in many parts of the world. The development at this time brought forth many environmental concerns which resulted in regulatory bodies introducing a broad variety of laws and emphasis to change consumer behavior in the 1960s and 1970s.

In the 1990s, scholarly interest in business and the environment resulted in a wide variety of initiatives that started to consider environmental concerns strategically for organizations, going beyond compliance. Early works on industrial ecology, industrial symbiosis, eco-industrial parks, and industrial ecosystems started to gain traction.

Regulations in Europe and Japan to address some land space and resources depletion concerns introduced policies for broader recycling and product-stewardship systems in the early-mid 1990s. These policies although national were focused on economic concerns, where Japan was going through broad stabilization of their economy and recycling and ecological industries were viewed as a way to improve economic growth in Japan. At the turn of the millennium, China's economy was growing dramatically. At this time in the early to mid-2000s, they introduce the circular economy as a broader policy. Industrial ecosystems were also growing as a topic. Thus, multi-industry and eco-park developments on a regional basis became the norm.

During this time, closing-the-loop initiatives and reverse logistics were being adopted at the supply chain level. We will present this issue some more in the next section of this chapter. But we first return to discussion about the evolution of the circular economy.

The circular economy was considered a broader national- and regional-level policy. The Ellen MacArthur Foundation sought to popularize circular economy principles through initiatives at multiple levels of analysis. Since that time, the concept of the Circular Economy has burgeoned in the literature with hundreds of new dimensions currently under investigation. Business models, technological solutions, and further infrastructural developments and investigations emerged. Literature reviews showed that the concept was quite broad and addressed by over a thousand articles by 2015. The number of publications and interest has more than doubled.

A major issue facing CE remains. What exactly is the Circular Economy (Korhonen et al., 2018)?

As the scholarly research—rather than policy and practice—has emerged, the terminology used to describe the Circular Economy concept has come under greater scrutiny (e.g., see Korhonen et al., 2018). It is an 'essentially contested concept' where different groups and actors will define the term that would be most beneficial to them. Some will view the Circular Economy as a job creating economic tool. Some may view it is an environmental sustainability management instrument. Others may view it as both or even a social innovation. The concept and its dimensions are still very much under increased scrutiny and development. For example, there are now financial funds seeking to invest in companies that contribute to or incorporate CE practices. The difficulty is finding the right evaluation tools to determine which companies fit within this context and which companies do not fit.

Overall, although many definitions may exist, we can stipulate that some aspect of extending the life of materials and products in the system or the reduction of materials and resources usage. The outcome will likely mean fewer emissions and improved resource use, but there is no guarantee. For example, if recycling—considered a typical CE practice—may result in greater energy use and produce polluting emissions. Thus, there is no guarantee that CE practices are environmentally or socially sustainable.

There are many aspects of CE that include multiple levels of analysis. One such characterization of various activities at macro, meso, and micro levels of analysis is summarized in Table 1.

Table 1 A multi-level representation of circular economy along various stages of a product's life cycle

	Micro (single entity)	Meso (supply chain—symbiosis association)	Macro (city, province, state)
Production	Cleaner production; eco-design	Eco-Industrial Parks Eco-agricultural systems	Regional industrial networks
Consumption	Green purchase and organizational operations	Linking and transporting materials for consumption between organizations—resource sharing	Regional programs to aid in sustainable consumption such as sharing, leasing, programs
Waste (by-product) Management	By-products and recycling	Waste trade markets. Joint industry efforts	Urban symbiosis
Support	Logistics and transportation, policies and laws, information platforms, capacity building, NGOs		

3 Green Supply Chain Management

As observed in CE, there are many levels of analysis and practice. The same can be stated for green supply chain management (GSCM). Arguably, GSCM is necessary for effective CE at each of its levels. GSCM focuses on the environmental management of supply chains or planning and operating supply chains in an ecologically sustainable way. Although many GSCM perspectives exist—we focus on the broader aspects of upstream, operations, downstream, and reverse logistics dimensions. In this case, we focus on 'green' rather than sustainable supply chains, which expands on environmental issues and typically includes broader social and economic dimensions.

Many GSCM-related practices exist. Literature points to five major GSCM practices (Zhu and Sarkis, 2004)—eco-design, green purchasing, internal environmental management, customer cooperation with environmental concerns, and investment recovery practices. Each of these practices is now generally described.

Eco-design focuses on products and processes. An efficacious approach for reducing waste is through improved design of waste prevention. The environmental implications of products and processes are *locked-in* at the design stages. These early stages represent how materials and architecture of a product or process are determined and to be used over their life. Eco-design includes product design for reduced consumption of material or energy, designing for reuse, recycling, recovery of material, component parts, design of products to avoid or reduce use of hazardous of products, and/or their manufacturing process. The linkage is both external and internal since suppliers and customers may be involved in eco-design.

Green purchasing of lead firms relates to the process and the product or service. It focuses on the upstream portion of the supply chain. The green purchasing differs from traditional purchasing processes. Green purchasing processes include using long-term contracts with environmental dimensions, avoiding poor environmental behaviors, supplier development to meet environmental objectives, auditing supplier environmental management systems, and integrating environmental performance into supplier selection, assessment, or evaluation.

International environmental management may be organizational operational practices and routines. It can be further classified using environmental management systems, resource consumption reduction, and pollutant emissions reduction. This classification can include managing prevention opportunities, and end-of-pipe management opportunities, and general governance and policy.

The significance of customer cooperation in greening a supply chain focuses on downstream supply chain activities. Many organizations encourage a closer relationship with customers to help them manage their downstream supply chain and address various customer and consumer-related environmental actions. Customer cooperation includes activities such as customer eco-design support, customer for cleaner production cooperation, green packaging, or transportation cooperation with customers.

Lead firms are applying concepts such as the circular economy to recover the investment, which is regarded as a key aspect of GSCM (Zhu and Sarkis 2004). Both the traditional '3R' (reduce, reuse, recycle) and the new '3R' (recover, redesign, and remanufacture) (Yan and Feng, 2014) have seen investigation and application. Investment recover also includes investment recovery (sale) of excess inventories/ materials, sale of scrap and used materials, sale of excess capital equipment.

These categories have been empirically evaluated (Zhu et al., 2008) and show a strong relationship to actual company practices although there are other possible considerations and developments such as using the green supply chain operations reference (SCOR) model to investigate GSCM processes, elements, and performance measures (Ntabe et al., 2015).

A graphical representation of various GSCM elements appears in Fig. 1. The diagram shows functions and activities. Research topics and practices appear in the bubble linkages. There are dozens of potential topics with thousands of research articles published on these various topics. The environmental concerns covered are broad.

4 Opportunities and Challenges for Circular Economy and Green Supply Chain Management

As evidenced by Table 1 and Fig. 1, there are overlaps in a number of areas for both CE and GSCM. For example, the *meso* level of CE is specifically targeting multiple organizations and alliances, which may include a supply chain context. In GSCM, we see that elements of CE are included in waste management (by-product development) and reverse logistics (which includes demanufacturing, recycling, and remanufacturing). Industrial symbiosis and finding partners for industrial symbiosis may also relate to both CE and GSCM.

We will identify some major opportunities at the intersection of both fields. Overall, we will consider this overview based on a technology, organization, and external environment (TOE) perspective. Within each category, we will also include economic concerns as they arise.

4.1 Technology

Technology includes soft and hard technology, product, process, and information technology. Technology and innovation management—many times—overlap in research and practice.

An example, relatively traditional technological concern relates to tools to evaluate environmental performance in supply chains and in the circular economy. Two popular technological tools include life cycle analysis/assessment (LCA) and mass flow analysis/accounting (MFA). LCA is evaluation of the environmental impact of products and processes across a product or material's life, which includes multiple stages of a supply chain (Tian and Sarkis, 2020) and/or circular economy framework (Peña et al., 2021). MFA typically analyzes raw materials from their origination into socioeconomic activities to material transformation across socioeconomic activities

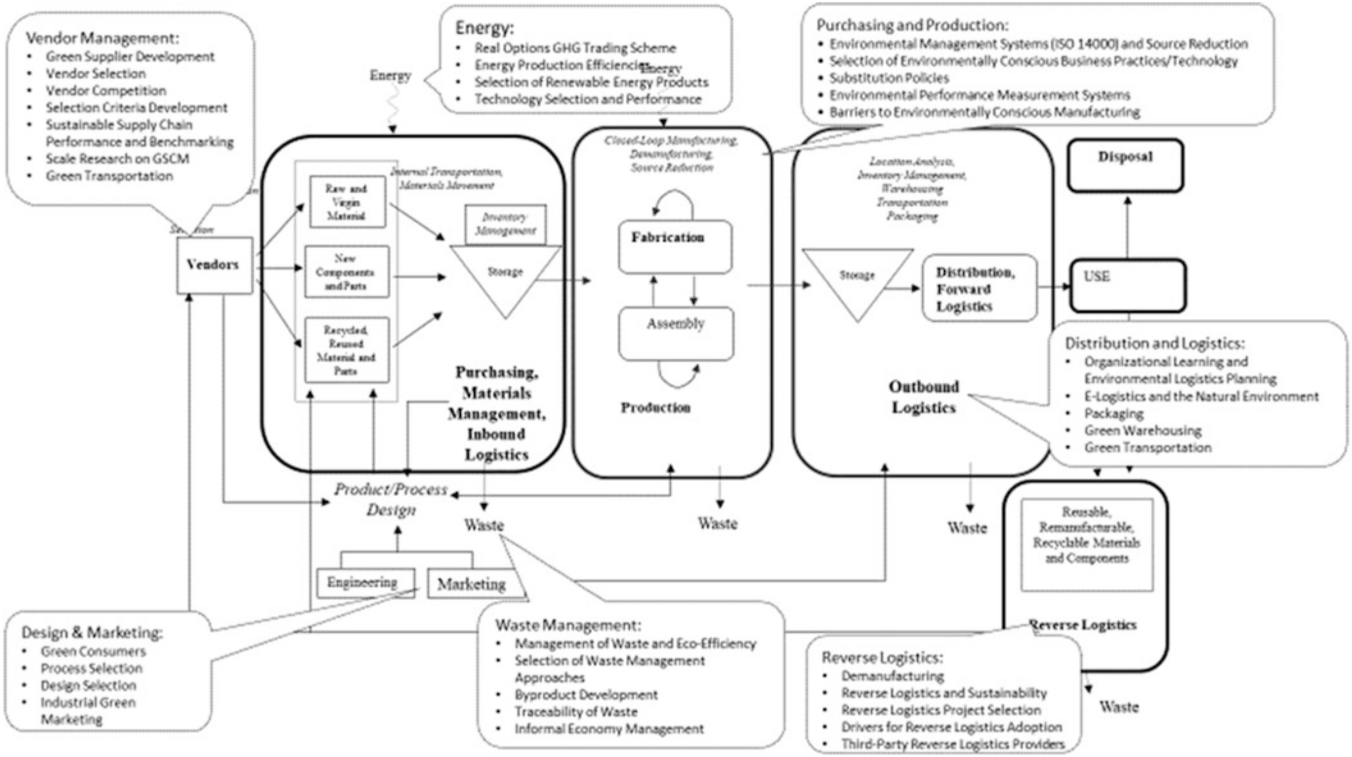

Fig. 1 Comprehensive of GSCM activities, projects, and programs for consideration across a generic supply chain. Including internal and external activities (adapted from Hervani et al., 2005; Kouhizadeh and Sarkis, 2018)

and the environment and has been well applied in CE settings (Tang et al., 2020). Its application to more organizational levels of the supply chain has been introduced (Hou et al., 2017, for example), but not as extensively as LCA.

These tools comprise information and process management for environmentally burdens and resource use at multiple levels of analysis, whether for the organization or for a group of organizations.

MFA and LCA have been utilized for both environments in simultaneous fashion—see Sassanelli et al. 2019, for a review of these and other tools.

Another technological aspect of GSCM and CE is the use of various industry 4.0 technologies (Bai et al., 2020; Esmaeilian et al., 2020). These sources would be considered a mix of hard technologies—such as robotics and computer-integrated machinery—in addition to softer technologies such as blockchain, virtual reality, and artificial intelligence. These technologies, although using higher levels of energy in many cases, can be useful to improve efficiency, reduce waste, improve transparency, traceability, and visibility especially given the digitalization of Industry 4.0 technologies (Sarkis et al., 2021). Each of these characteristics can provide significant governance and operational sustainability improvements.

Let us consider that technological support for traceability as a practical example for CE and GSCM improvement. Materials and products need to be managed throughout the supply chain and after usage. The management of the products life cycle from raw material to consumer and back again is something that the company OPTEL tries to integrate in its global possibility systems linked to blockchain distribution ledgers and the Internet of Things (IoT) (https://www.optelgroup.com/sustainablity/). They also purport that these capabilities can increase recycling, recycle packaging, reduce resource usage, and substantiate claims.

These multiple aspects can help manage the supply chain. In addition to governance and monitoring, human behavior can also be managed throughout the supply chain and for circular economy purposes.

These exemplary technological opportunities do not come without challenges. The challenges for these and other technologies used across multiple functions and multiple organizations are manifold. The challenges range from acceptance of untested technologies within a company and its partners to actual technological limitations such as scalability and maturity of the technology (see Kouhizadeh et al., (2021), for an example evaluation). There may also be concerns related to proprietary information being shared and general adoption across multiple parties who have different strategic and operational outlooks. For example, a sub-supplier may not wish to invest in technology that would support GSCM and CE since their business for an organization adopting these practices might be minimal.

These examples of technologies and challenges relate to various organizational elements and considerations—which we now discuss.

4.2 Organization

Organizational concerns relate to policies, practices, and processes—to name major dimensions. Organizational research focuses on management within organizations and these items relate to making sure businesses maintain competitiveness, profitability—in for-profit organizations—and delivering on customer expectations. Much of the concerns depend on the perspectives and levels of analysis within and across organizations. Strategic, tactical, and operational concerns are typically the concerns in these environments. We will identify examples of each including opportunities and challenges.

Strategic Concerns with advancing GSCM and CE simultaneously have to do with long-term plans and designs that will allow both practices to be integrated. Institutional and stakeholder pressures play strong external roles that will likely cause organizations and their networks to adopt these practices (e.g., Bag et al., 2021; Alkhuzaim et al., 2021). Specifically, it is likely that organizations and supply chains will react greatly to coercive institutional pressures from regulatory stakeholders. Stakeholders such as corporate partners and competitors are likely to cause mimetic—benchmarking and competitiveness—pressures, while communities and industrial association stakeholders are likely to be focused on building norms and rules—that also include regulatory voluntary initiatives—that result in normative pressures.

These pressures are typically identified for strategic purposes and will cause organizations to adopt long-term and broad strategic programs to help address concerns related to GSCM and CE. One of the biggest aspects of adopting strategic CE and GSCM programs and from an organizational perspective is to get buy-in from top management teams (Jabbour et al., 2019). Getting approval to broadly implement these programs may require c-suite decision-makers and relate closely related to sustainability strategies of organizations.

Strategic designs based on longer-term management and engineering requirements include partner development and selection will be critical in these circumstances as well as network designs. An important strategic decision, as an example, is whether to contract with a third-party reverse logistics provider or develop a network managed by organizations partnering to deliver products along a forward supply chain. This type of decision may depend on multiple partners within the supply chain and a determination of where responsibility holds.

For example, in Canada, Whirlpool Corporation, a manufacturer of white goods appliances, was required to set up a reverse logistics and closed-loop system to take back its appliances as part of an extend producer responsibility effort (Mark and Wood, 2011). The decision was required by the provincial government. In this case, the pressure was likely coercive and somewhat normative as communities expected to have the material flows to be managed in a circular fashion to improve solid waste management. The decision had to do with whether Whirlpool's network—including retailers—would be involved in the system or have a third-party manage it. Millions of dollars were involved in this decision and it would include considering a 20+ year lifecycle of major appliances.

Many other strategic concerns exist within and across organizations for planning, design, and implementation of various CE and GSCM programs. Proactive environmental strategies and policies may set the stage for these events. A critical aspect of strategic planning is making sure there are availability and integration of multiple strategic performance metrics—see Kazancolgu et al. (2018) for an extensive review of strategic and operational metrics linking GSCM and CE.

Globalization of supply chains and CE requires significant strategic effort to plan for markets and partner selection in the process—some regulations cross country boundaries and need a much broader outlook—some of these issues are described in the external environmental portion of this section. Broader organizational systems to cover global dimensions are needed for CE and currently rarely exist (Geng et al., 2019). Additionally, some of the technological decisions and issues require strategic financing and innovation management concerns. For example, blockchain technology is necessarily a strategic program which may require cryptocurrency adoption—a technological financing solution that can greatly influence CE and GSCM practices.

Operational and Tactical Concerns can be integrated into a single grouping. Organizational size, industrial sector, and even geographical location may cause these two levels of concerns to overlap or shift depending on the context. That is some tactical concerns in one situation, may be considered operational issues in other contexts. Tactical concerns would include packaging concerns in a CE environment (Meherishi et al., 2019), quarterly or annual inventory holding policies (Rabta, 2020), or consideration of managing new project or program based on a CE strategic goal (Sanchez and Haas, 2018)—such as the previous example of Whirlpool, after making a strategic decision trying to set up the system that will operate in a new reverse logistics network.

Operational activities will include aspects such as training of workers, scheduling deliveries and collections, and operational disassembly planning—as examples that would affect various aspects of the GSCM and CE activities.

Numerous exemplary studies exist, but in each, complex characteristics associated with multiple dimensions and trade-offs require consideration of models or theories to support and explain GSCM and CE practice and integration. Many of the organizational concerns focus on tangible business issues such as technology and financing—yet more intangible concerns related to reputation (Quintana-Garcia et al., 2021), morale, motivation, and leadership (Faraz et al., 2021; Graves et al., 2019), and learning are just as critical for long-term success of integrating and implementing these greening and CE programs (Sarkis, 2009; Sawe et al., 2021).

Within each of these organizational areas, concerns on how to plan, develop, test, implement, and maintain GSCM and CE aspects exist opportunities. GSCM and CE capacity—as previously observed—can help develop and maintain competitiveness. The opportunities exist at multiple levels, within functions, as well as inter-functional possibilities. For example, operational improvements from less waste can be balanced with new markets generated from by-product manufacture.

4.3 External

The external environment to the organization and supply chain aspects that are beyond organizational control also represent a variety of challenges and potential opportunities. As alluded to in previous sections, multiple institutional fields—and pressures—along with a variety of external stakeholders play a role in managing these external challenges. Major external stakeholders include governments, communities, consumers, NGOs, and competitors. Each provides challenges along with opportunities. We briefly describe some of these items based on these stakeholder requirements.

Government actions are typically associated with regulatory processes and mechanisms that govern organizational and supply chain practices. Over the years, various regulatory acts have required some form of adoption of GSCM and CE practices. For example, two of the most broadly applied—initiating in Europe—are the waste electrical and electronic equipment (WEEE) (Bressanelli et al., 2020; Ongondo et al., 2011) and restriction of hazardous substances (RoHS) regulations (Li et al., 2021). These regulations have implications for why organizations will adopt GSCM and CE practices, but also have implications for how they should be managed including the type of resources and partnerships that would need to be developed.

A recent government action in the European Union that is likely to further motivate GSCM and CE is emergent 'due diligence' laws for supply chains (see Sarkis et al., 2021). These laws will fine and penalize companies whose supply chain members are viewed as 'bad actors'. Companies that do business with them would be held liable. There are uncertainties and complexities associated with these new regulations, but it is likely that even the possibility will motivate organizations to find practices which they can control. CE is one such practice if a company used extended producer responsibility (EPR) actions within CE.

Communities are also important stakeholders. These communities will or will not allow some companies to do business in their regions unless they can show they are good corporate citizens (Jaegler and Sarkis, 2014). Boycotts and the 'not in my backyard' (NIMBY) syndrome have limited companies and industries from locating in some regions. Having GSCM and CE practices (such as reverse logistics) shows a good faith effort for organizations to consider broader social and environmental sustainability concerns (Sarkis et al., 2010).

Consumers play a significant role in causing companies to alter practices to be more sustainable from GSCM and CE practices. For example, eco-labels are meant to attract sales to both industrial and individual consumers. CE eco-labels and practices are only starting to gain traction (Meis-Harris et al., 2021), whereas GSCM supplier labels have existed for years for multiple products and industries. Some of the more basic and longer-lasting product eco-labels that fit into both categories are recycling labels. A basic concern and issue associated with eco-labels is how trustworthy the labels for what they purport to do. For example, recycling labels may have differing levels of recycling depending on the locality or product. Eco-labels are often not regulated and consumer trust in them is not guaranteed (D'Souza et al., 2021).

NGOs play a variety of roles with organizations and supply chains and their GSCM and CE practices. Coercive pressures may exist where activist NGOs would cause organizations to carefully evaluate their supply sources such as with McDonalds being forced to not consider soybean from Brazil. Mimetic and normative pressures based on NGO-supported standards organizations. NGOs can also play an important role in providing visibility and traceability into the supply chain (Kazancoglu et al., 2021); many of these are supported through eco-labels and certifications.

Competitors set norms and benchmarking pressures. There will be greater diffusion in CE and GSCM practices as competitors start to see competitive advantages. Organizations would be pressured to adopt many practices to be able to compete as the hurdles to participate rises. For example, in CE and GSCM, organizations will become more efficient with resources and materials use. This allows them to achieve higher margins and profitability, which allows them to further invest in these practices. Additionally, sometimes in CE practices joint efforts are required even amongst competitors. As an example, helping close the loop on plastics so these plastics do not flow into the oceans may require having a market and agreement amongst competitors to provide markets and designs to be able to support CE for plastics.

5 Logistics and Supply Chain Manager Skills for GSCM and CE

There are standard skills such as personal and technical skills that are necessary for logistics and supply chain manager skills. Communication, teamwork, project management, and analytical skills are all basic and required for almost any managerial position. We identify additional skills here.

First and foremost, the understanding of environmental and social sustainability implications is necessary. GSCM and CE are both very closely related and impact sustainability. Managers with good broad knowledge of how their practices influence various environmental and social concerns will allow them to make better decisions. This would mean building a knowledge set around the major environmental issues and how various practices relate to them. For example, a major critical environmental concern at this time is reducing carbon emissions to help mitigate climate change impact.

Building environmental or social management skills will differ based on the industry, product, and potential regional location. Considerations in this case would be things such as understanding trade-offs between various sustainability concerns. That a decision can involve improvement in some sustainability dimensions may also mean degradation in other dimensions. These nuanced understandings will be necessary for thoughtful integration of CE and GSCM practices into the organization.

Another important required skill, related to expanding knowledge into environmental and sustainability issues, is being able to communicate and converse across transdisciplinary boundaries. The science and engineering aspects of GSCM and CE are clear, but there are also multiple stakeholders that would need to be managed and communicated. For example, community and competitor stakeholders will be involved in most CE and GSCM practices. Expanding the knowledge of how build and develop relationships with external stakeholders and non-logistics and non-supply chain management actors. Rarely do these managers have to work with NGOs, it is more likely in these situations that such working relationships and understanding will need to be developed.

Thus, teamwork skills expansion to include broader sets of stakeholders will likely be needed.

The managers in this field may also need to learn to work with new technologies. Knowing how to integrate material and process technologies for CE practices such as by-product development or remanufacturing will require understanding new technologies and alternative product and material designs.

Numerous information technologies including blockchain technology, IoT, and sensor technology are all emergent areas that can support CE and GSCM. Knowing how to use and apply this technology will be necessary. Also, the information from these systems can be substantial. Big data and data analytics capabilities to understand how to analyze the data and even use it for predictive CE analytics will be required. Additional skills related to building and understanding sustainability analytics for performance measurement systems are required in the CE and GSCM future.

Overall, the skills required are based on expanding current skills. Each supply chain and logistics manager requires communication, behavioral, interpersonal, and technical skills. These skills each require expansion. As observed communicating with broader stakeholder groups, improved interpersonal skills that reach out to external communities and stakeholders, expanding knowledge to include CE and GSCM or sustainability knowledge, and technical skills that include new materials and information management.

6 Conclusion

The world is facing unprecedented resource and ecological pressures from human activities. The Anthropocene has meant that human impact on the natural environment and the resources it provides is under great strains. Industrial and supply chain activities are causing a major fraction of this burden. The circular economy and green supply chains offer opportunities to mitigate these impacts.

We also argue that CE and GSCM offer substantial opportunities for organizations to address and balance environmental, social, and economic sustainability concerns. Both topics are intertwined and support each other; we have provided insights into various activities and practices at multiple levels. Logistics and supply chain management practitioners and scholars need to adjust their perspectives when it comes to these broader issues and concerns.

The complexities of these two supply chain-related practices mean many challenges, but also include opportunities. We have provided some challenges and opportunities associated with CE and GSCM using a technology, organization, and external perspective. The emergent perspectives require skills expansion—building on current skills that exist to include relationships with multiple stakeholders and new organizational forms and technologies.

We have provided a brief overview and provided additional references so the readers can go into more depth. This is an important area of research and application that organizations and managers will need to function in the next decade and beyond.

Management Perspective on Green Supply Chains, Circular Economy, and the Need of Technology

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There is no doubt that mitigating and stopping climate change needs our attention. The Paris Agreement on Climate, the activities before and the activities after the agreement have clearly defined the goal to limit global warming to 1.5 degrees before the 1990.

The society, companies around the globe, governments, non-governmental associations, individuals, and especially those from the next generation many currently studying or just entering business life are committed to contribute to this change to make it happen. For the generation running the governments and being in key business or associations, it is a huge responsibility, which they carry with them when we integrate young people with this engagement as interns, working students, bachelor or master students or if we hire them and when defining and transporting vital skills for green supply chain and the circular economy.

What skills in those areas does the next generation need to support and in some cases earlier than expected are needed to lead this change in their area of existing or upcoming responsibilities?

All short-term measures to reduce the carbon footprint in everyday life, in school, at the university, at transportation, or in the companies' manufacturing areas are needed and welcome. Skills like measuring the carbon footprint, analyzing the root cause of carbon footprint increasers, and identifying circular economy opportunities and enablers are the base. Recognizing that many economic goals and ecologic goals go hand in hand—like Lean manufacturing or Lean for complex flow production [Lean for complex flow production; https://en.wikipedia.org/wiki/Lean_CFP_driven]—can speed up the skill increase, due to the well-established structure of these domains: waste, all 'muda' should be avoided. Understanding the principles of recycling, remanufacturing, and reuse helps the needed skills for the circular economy [Kahneman prospect theory: https://de.wikipedia.org/wiki/Prospect_Theory].

(continued)

If we talk about the bigger picture and especially about the future needed skills in the high-tech industry, like the semiconductor industry, some of the skills go beyond the classical skills for the next generation mentioned above. Often in history of humankind, it was the next technological advancement solving the shortfalls of the previous ones.

Semiconductors with its sensors and actuators can 'see' where energy is lost and can 'turn' the wheel to avoid this waste. This sounds easy but it requires theoretical and practical skills to apply it. It starts from selecting and implementing the right measurement or using existing data. It continues with connecting them in the right way and finds patterns and hidden knowledge by analyzing it. These skills are coming with engineering and supply chain skills, and cover semantic technologies to avoid waste in data search to quickly find the right data and of course AI and Deep Learning skills for patterns and hidden knowledge (Ehm et al., 2019).

The potential of technology can for example be seen in the CO_2 balance published as annex to the yearly report of Infineon Technologies AG (Infineon sustainability report)—see Fig. 2. One gram spent for CO_2 to produce semiconductor yields in average 35 times more CO_2 saved in its application over the lifetime. The semiconductor industry itself is characterized by volatile demand, fast technological advancements and has a highly capital intense manufacturing.

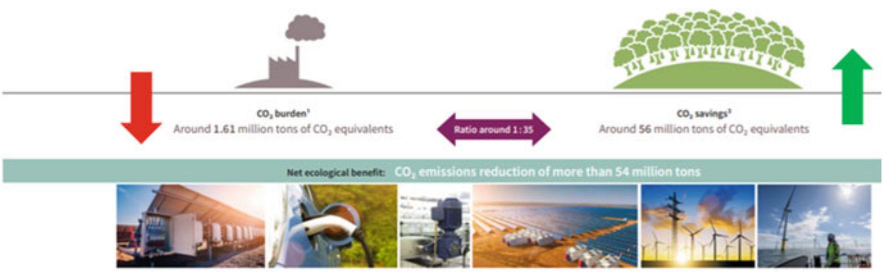
Most (>50%) of the CO_2 usage depends on fixed CO_2 need due to electricity for cleanrooms in factories or the machines (like Implanters), and only a very small percentage is used to transfer the tiny chips around the globe for the next production steps. This is because many wafer production sites are located in the USA or Europe, while Assembly and Test is mainly located in South-East Asia. Let us have a look at flexibility need and its impact to a green supply chain. No flexibility means that at a given forecast (F/C) accuracy (let us assume 80%) one factory is utilized only to 80% and the other one is overloaded and thus fixed to 100%. The average CO_2 used for a normalized product in this setup per product would be more than 5% higher than at 100% F/C Accuracy. However, if there is full flexibility, the increase is less than 1%, despite the transport. Figure 3 visualizes the ecological optimum between Forecast Accuracy and Flexibility from a simulation study. Hence, besides taking the CO_2 burden of transport serious at every detail, it requires academic skills applied to practical needs to find the ecologically best way in every setup.

A similar thinking is needed for new technologies like advanced semiconductors for a higher balance as shown in Fig. 2, or it is even required the application of Quantum technologies. The latter one will support solving NP-hard knapsack Problems and Travelling Sales Man Problems in supply chain and global Logistics much more accurate toward a global optimum.

(continued)

Analyzing the Forecast Accuracy in supply chains containing semiconductors, the bullwhip effect causing an amplification of demand fluctuations in upstream nodes of supply chains (and thus waste and inefficiency) is a further hurdle for real green supply chains with less waste. But how to overcome this bullwhip effect, which can be explained by the behavior of humans who tend to order more than needed when being out of stock and order less than needed when there is a surplus of stock—as explained well in Kahneman's prospect theory (Kahneman prospect theory: https://de.wikipedia.org/wiki/Prospect_Theory). It seems that the Bullwhip effect and the inevitable need of risk taking must go hand in hand for prosperity in the needed capitalistic startup mentality for democracy. However, game theory and serious games can teach the next generation that the disadvantages of the bullwhip can be avoided by using AI-based forecasts in areas where the AI machines are in their comfort zones and humans will accept those forecast even if not explainable but take over when the AI machines are not in their comfort zone.

The next generation needs the skills to use upcoming technologies like advanced semiconductors, Quantum technologies (QUTAC – Quantum Technology & Application Consortium https://www.qutac.de/), and semantic technologies (Ehm et al., 2019). This is needed to harvest the benefits of digitalization with AI for green supply chains and circular economics. This skill set will also help avoiding the green supply chain enemy (being the bullwhip effect), but in order to be really successful, the next generation needs social science know-how, which includes—beyond prospect theory and game theory—also the capability of discrete event, agent-based, and system dynamics simulation, as well as confidence in how to learn with and develop serious games to test out new environments in a risk-free simulation and gaming environment.



Source : Sustainability at Infineon 2020 – Infineon Technologies

Fig. 2 CO_2 balance of a semiconductor company

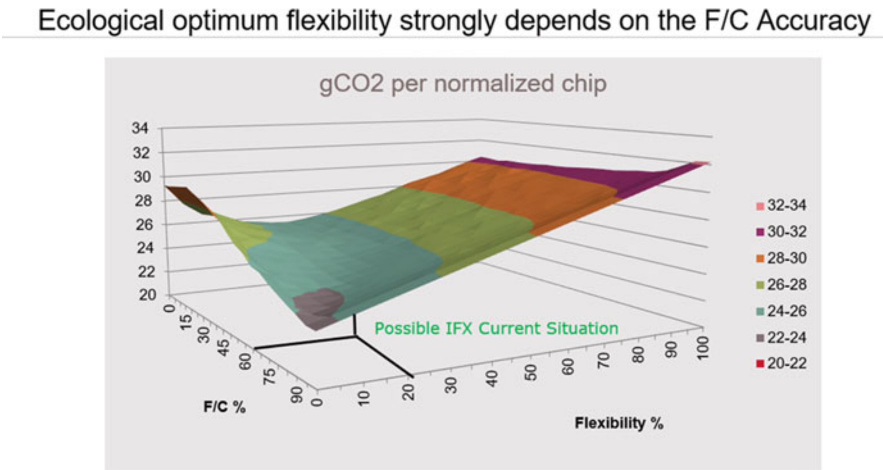


Fig. 3 Ecological optimum depends from the F/C accuracy and the Flexibility (Flexibility as an Enabler for Carbon Dioxide Reduction, 2018)

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Preparing Logistics for the Low-Carbon Economy

Alan C. McKinnon

1 Introduction

During the working lives of new recruits to the logistics management profession, carbon emissions from logistical activity will have to drop to a small fraction of their current level. These managers will probably have to attach at least as much weight to decarbonisation as to meeting the traditional goals of economic efficiency and service quality. This will require new mindsets and skillsets and a re-evaluation of long-accepted paradigms, principles and procedures. Many companies are only beginning to grasp the magnitude of the changes they will have to make to compete effectively in a low, and ultimately zero, carbon world. Many of those that have publicly committed to being 'net zero carbon' are struggling to see how this can be achieved, even over a 20- to 30-year period. This applies particularly to logistics operations because their emissions are generally acknowledged to be 'hard-to-abate', being overwhelmingly powered by fossil fuel and subject to steeply rising demand. For the current and future generations of logistics managers, decarbonisation will therefore present an enormous challenge. This chapter examines the nature and scale of this challenge and the capabilities that company management will have to acquire to meet it.

The decarbonisation challenge can be defined in both planetary and governmental terms. Planetary systems set the climatic, geophysical and ecological boundaries for long-term sustainable development. On the basis of scientific understanding of these systems, governments, and the international organisations to which they belong, then set emission reduction targets and devise policies to achieve them. A total of 197 countries signed the 2015 Paris Accord committing to keep the increase in average global temperature between 1850 and 2100 to 'well below 2 °C'. Two years later, the Intergovernmental Panel on Climate Change (2017) urged governments to

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adopt 1.5 °C as the upper limit in order to mitigate the adverse effects of global warming and the risk of crossing climatic ‘tipping points’ which would pose an ‘existential threat’ to our civilisation (Lenton et al., 2019). As average global temperature has already risen 1.1 °C since pre-industrial times (WMO, 2020) and the seven warmest years on record have occurred since 2014 (NOAA, 2021a), staying within the 1.5 °C limit demands ‘*immediate and concerted action*’ (Mann, 2021). According to the IPCC (2017), for us to have a two-thirds chance of staying within this temperature limit, future emissions of CO_{2e} would have been restricted to 420 Gtonnes. Given the annual emission rate in 2018, this ‘carbon budget’ would be exhausted within 8–10 years. The pandemic-induced reduction in the rate of CO_{2e} emission in 2020, of around 7% (NOAA, 2021b) has only marginally extended this period. The COVID crisis has, however, given political and corporate decision-makers a sense of the magnitude of the economic and social transformation that will be required to arrest global warming.

Before the pandemic struck many national governments, cities and regions had declared a ‘climate emergency’, the United Nations had launched its ‘Race to Zero’ initiative (UNFCC, 2020a) and the EU had committed to making Europe the first carbon neutral continent by 2050. This was partly in response to the results of new climate modelling by the IPCC and others, but also to mounting evidence of the devastating effect of extreme weather events whose frequency and intensity are being amplified by climate change. In addition to their huge toll in death and suffering, destructive weather events attributable to climate change are already estimated to be costing the global economy around $195 billion per annum, a figure rising by 20% per annum (Centre for Risk Studies, 2020). Widening recognition of the gravity of the situation has prompted a step-change in the business response to climate change. By late 2020, over 1100 companies had pledged to become ‘net zero’ carbon (UNFCC, 2020b), usually placing decarbonisation at the heart of their economic, social and governance (ESG) strategies.

It is against this background that logistical activities have to be decarbonised. Overall, they account for 10–11% of energy-related CO_2 emissions worldwide, 85–90% of which come from freight transport and the remainder from warehousing and terminals (McKinnon, 2018). The International Transport Forum (2019a) has predicted that, on the basis of current policies, freight-related emissions would rise by 118% between 2015 and 2050. Even in its ‘high ambition’ scenario, which would see the average carbon intensity of freight transport drop from 24 to 9 grams of CO_2 per tonne-km, total freight emissions would still increase by just over a fifth by 2050, driven by a 3.3 times growth in global freight demand over the next 30 years. Clearly, this ‘optimistic’ scenario is incompatible with governmental and corporate targets for economic activity to be ‘net zero’ by 2050.

A case can be made for logistics to be exempted from the net zero target on the grounds that full decarbonisation will be exceptionally difficult to achieve. The EU’s ‘smart and sustainable mobility strategy’, for example, has set a target of reducing CO_2 emissions from transport by 90%, rather than 100% (European Commission, 2020), relying on other sectors to become carbon negative and thereby compensate for transport’s emission ‘overshoot’. The concept of ‘net zero’ after all allows for such inter-sectoral offsetting. Any such concessions, however, are likely to ease the pressure to decarbonise freight transport, and logistics as a whole, only marginally over the next few decades. What then will those planning and managing logistics over this period need to do to get logistics emissions down to an acceptably low level, if not to zero? I answer this question at length in my book on the subject describing a procedure that companies can use to develop a logistics decarbonisation strategy (McKinnon, 2018). This chapter summarises several of the key stages in this procedure and concludes with a discussion of the skills that will be required to manage them effectively. It also incorporates some of the results of a recent survey of ninety European logistics executives on the subject of decarbonisation (McKinnon and Petersen, 2021).

2 Measuring Logistics Emissions

Accurate and consistent measurement of GHG emissions is a pre-requisite for any decarbonisation programme. It allows companies to build an emission profile of their logistics operations, monitor trends in emission levels and, depending on the degree of data disaggregation by activity and location, help to show where decarbonisation efforts should be concentrated. In addition to supporting the internal management of emissions, carbon measurement is often required for external purposes. Companies may wish voluntarily to report their GHG emissions, through schemes such as the Carbon Disclosure Project (CDP), to publicise their environmental commitment and achievements. They are, however, coming under increasing pressure from customers and investors to report their emissions externally. This is particularly the case for logistics service providers (LSPs) whose clients are demanding emission data specific to individual contracts and/or consignments. With so much logistical activity now outsourced, much of the onus for collecting CO_2 data rests with LSPs. The European logistics executive survey found that LSPs have a greater capability than shippers to measure and report carbon emissions at a disaggregated level. This is hardly surprising as logistics is their core competence and they have more access to the relevant operational and energy data. The ability to provide emission data is likely to become a qualifying criterion for LSPs in the tendering process. Shippers, however, are likely to come under similar pressure from their customer base as carbon transparency becomes the norm across supply chains. This trend will be hastened by the proliferation of emissions trading and carbon taxation schemes, which legally oblige companies to report their emission levels for fiscal purposes. According to the World Bank (2021), 64 such schemes are in operation or planned which if fully implemented would cover 22% of global GHG emissions. At present, almost all logistics activities are exempted from carbon pricing/taxation schemes though it is only a matter of time before their decarbonisation is similarly monetised.

A company measuring its logistics emissions for the first time must resolve several issues:

(i) *Which gases should be measured*? As carbon dioxide accounts for well over 90% of GHG emissions from logistics, it is common for companies to confine their calculations to this gas. Those powering some of their transport operations with gas, such as compressed or liquid natural gas (CNG or LNG), should include methane in the calculation, particularly as it has a global warming potential (GWP), around 21 times that of CO_2 (over 100 years) when leaked into the atmosphere from vehicles, vessels or pipelines (UNFCC, 2021). Fugitive emissions of refrigerant gases from the cold chain should also be recorded by companies moving and storing temperature-controlled products, because their GWP can be over 11,000 times that of CO_2!

(ii) *What should be included in the calculation*? Broadly speaking, four types of boundary can be drawn around the emission calculation:

Activity boundary: This relates to the definition of logistics and a company's division of managerial responsibility for the function. There is a consensus that core activities such as freight transport, storage and materials handling should be included, but should the calculation also include, for example, emissions from logistics-related IT, product customisation undertaken within warehouses and the recycling of packaging waste? As a general rule, it is desirable to make the calculation as inclusive as possible.

System boundary: NTM (2017) differentiates five system boundaries (SBs) nested around a logistics operation, extending from vehicle exhaust emissions (calculated on a 'tank-to-wheel' basis) (SB1), through 'well to wheel' emissions taking account of the energy supply chain (SB2) to calculations incorporating emissions from the maintenance of vehicles, warehousing and infrastructure (SB3), their manufacture and construction (SB4) and administrative activities/staff commuting (SB5). Most of the currently available logistics emission data falls within SB1 and SB2, though as emission measurement evolves the calculation boundary will expand to provide a more holistic view of logistics' carbon footprint.

Organisational boundary: This boundary was defined by the Greenhouse Gas Protocol as being Scope 1 for direct emissions from assets owned and operated by a company, Scope 2 for emissions associated with electricity generation and Scope 3 for indirect emissions by suppliers and contractors working on the company's behalf (WBCSD/WRI, 2004). Because of the difficulty of obtaining Scope 3 data, most corporate emission reporting was initially confined to Scopes 1 and 2. As a result of methodological advances and greater data sharing, it is now common for businesses also to report their Scope 3 emissions.

Hierarchical boundary: Relating to the degree to which logistics emission data is disaggregated. At the highest level, a company might simply calculate and report an overall figure for the logistics function. This figure can then be broken down by, for example, business unit, premises, vehicle fleet, individual vehicle, customer delivery and consignment. The greater the degree of disaggregation, the more detailed is the insight into the emission-generating process and the more granular the emission reporting service for customers. There has, nevertheless, been a debate over the feasibility, desirability and cost-effectiveness of carbon auditing end-to-end supply chains at a product level (McKinnon, 2010).

(iii) *What method of calculation should be used?* There is a major distinction between energy-based and activity-based approaches. The former is more accurate but can only be applied when a company knows how much energy of differing types is used in the logistics operation. These energy figures can be multiplied by energy-based emission factors, such as gCO_2 per litre of diesel or per kWh of electricity. In an ideal world, carriers would share their energy data with clients, but for commercial reasons they are often reluctant to divulge information about a category of expenditure representing, in the case of trucking companies, around a third of their total costs. In the absence of energy data, a shipper must use surrogate measures of the level of logistical activity, such as tonne-kms, TEU-kms or warehouse throughput and multiply them by carbon intensity values (e.g., gCO_2 per tonne-km) averaged at a national, modal or sectoral level and published in official tables, such as those of DBEIS/DEFRA (2020) and ECTA (2011). The use of these default values renders the calculation much more approximate and less able to discern company-specific changes in carbon efficiency.

When disaggregating freight transport emissions, one encounters a series of allocation issues. For example, how should a carrier divide emissions among multiple consignments of varying size and density occupying the same vehicle making a less-than-truckload (LTL) delivery? In the early days of logistics carbon auditing, different rules were proposed for such allocation problems frustrating efforts to compare emission estimates on a consistent basis across transport modes and industry sectors. In Europe, the international standards agency CEN (2012) issued guidance on how carbon emissions from transport should be measured. Since 2014 the Global Logistics Emissions Council (2019) has worked hard to harmonise the measurement of logistics emissions at a global level across all transport modes and for transhipment facilities. Its frameworks and methodology are now widely adopted and are soon to be incorporated into a new ISO standard for emission measurement in transport. In a related initiative, Fraunhofer IML have devised standards for the measurement of emissions from '*transhipment sites, warehouses and distribution centres*' (Dobers et al., 2019).

The calculation of logistics emissions has not only been facilitated by the development of measurement and reporting standards. It has also benefitted from the compilation of emission factor databases by government agencies such as DBEIS/DEFRA (2020) in the UK, ADEME in France and SmartWay in the USA, and by the construction and refinement of online emission calculator tools such as EcoTransIT and TRACKS.

3 Setting Emission Reduction Targets for Logistics

Once companies have carbon footprinted their logistics operations, the next step is to set realistic targets for shrinking this 'footprint'. Until recently, most of these targets related to the carbon intensity of logistics, in other words they aimed to reduce emissions relative to an index of logistical activity, such as tonne-kms, vehicle-kms or warehouse throughput (McKinnon and Piecyk, 2012). Firms were understandably hesitant about adopting targets that might jeopardise future business growth. Such targets, however, are not compatible with the governmental and planetary imperative to reduce total emissions. In recognition of the seriousness of the climate threat, many companies have since migrated from carbon intensity to absolute carbon reduction targets. The recent survey of European logistics executives found that 40% of their companies are now setting absolute targets. This figure includes 8% of the companies which have adopted emission reduction targets in line with the Science Based Target Initiative (2019). This Initiative was established in 2014 to help businesses align their targets with the climate science and aim for net zero status by 2050 or earlier. By early 2021, just over 1100 companies had science-based targets in place, 40% of them consistent with the objective of keeping the increase in average global temperature by 2100 within the 1.5 °C limit. Logistics businesses accounted for only around 5% of this total, though the logistics operations of companies in other sectors will be covered by their corporate-level targets.

Companies which outsource their logistics indirectly adopt the carbon reduction targets of their LSPs. Many of the larger LSPs have set ambitious targets for cutting their total emissions, effectively putting their clients' logistics on a steep decarbonisation trajectory. In many cases, however, the LSPs' targets apply only to Scope 1 and 2 emissions and exclude the Scope 3 emissions from carriers to whom LSPs sub-contract much of their transport. A recent European study examined the difficulty of engaging small- and medium-sized road carriers in the decarbonisation process (Toelke and McKinnon, 2021). There are over half a million such carriers in Europe, undertaking much of their haulage work on a sub-contract basis for large LSPs. While most carriers recognise the need to cut carbon emissions, relatively few see much commercial benefit in doing so and many claim to lack relevant knowledge of the subject. The high degree fragmentation in the trucking industry is clearly an obstacle to the dissemination of good practice in carbon measurement, management and target setting.

It is considered good practice in logistics emission target-setting to adopt a 'bottom-up' approach. This involves analysing decarbonisation options in advance and assessing the GHG savings they are likely to yield over differing time periods. This analysis should also have a financial dimension as account must be taken of the relative cost-effectiveness of the various measures and what can be afforded within the available budget. Marginal abatement cost (MAC) analyses have been conducted to compare logistics decarbonisation measures in terms of both their potential carbon savings and carbon mitigation costs (e.g., Greening et al., 2019). Some of these analyses have been operationalised as online tools to help companies customise packages of measures likely to deliver targeted levels of carbon savings within budgetary constraints. A common finding is that many decarbonisation initiatives offer both economic and environmental benefit and are self-financing in the short to medium. Many of them, after all, involve improving operational and energy efficiency and so are little more than good business practice. In the survey of European logistics executives, 40% estimated that half or more of carbon-reducing measures also save money (McKinnon and Petersen, 2021). This suggests, therefore, that, as far as logistics decarbonisation is concerned, there is still a significant amount of 'low hanging fruit' to be harvested. The next section reviews the available 'fruit', both low-hanging and currently less accessible technically and financially.

Companies sometimes set targets for cutting logistics emissions that exceed the reductions that can be achieved internally within financial and time constraints. They might then resort to carbon offsetting to 'close the gap'. This involves paying other organisations to cut emissions on their behalf by sequestering GHGs through afforestation, energy efficiency programmes, methane capture, etc. Concerns have been raised about the additionality, permanence, scalability and legitimacy of carbon offsetting schemes, but they are now quite widely used in the logistics sector. Several large LSPs and freight forwarders offer carbon offsetting services to clients effectively rendering the delivery of parcels, containers and other types of consignment carbon neutral. Accreditation systems have given businesses greater confidence in the integrity of carbon offsetting, though there remains a danger that it is seen as an 'easy option' and relatively inexpensive way of avoiding or delaying more difficult decarbonisation decisions.

The use of carbon offsetting by logistics companies has also been criticised for draining resources that could have been invested in decarbonisation efforts within the logistics sector. Only 0.25% of voluntary carbon offset expenditure in 2019 went into the transportation sector (Donofrio et al., 2020). A recent White Paper by the Smart Freight Centre and DHL argues that '*aligning carbon offset investments with supply chain climate impacts—a practice referred to as carbon insetting—would unlock vital funds that could be used to decarbonize the global freight transportation network*' (Greene et al., 2020). They envisage carbon inset funds, retained within the logistics sector, accelerating the adoption of sustainable fuels, decommissioning of older equipment, retrofitting of vehicle engines and uptake of logistics efficiency measures. The creation of such a logistics carbon inset market would provide supplementary finance for these initiatives, helping the sector as a whole to meet its emission reduction targets.

4 Reviewing Logistics Decarbonisation Options

These options fall into five general categories.

(a) Reducing the demand for logistic activity.

If the International Transport Forum (2019a) prediction of a trebling of freight tonne-kms between 2015 and 2050 were to materialise, it would be virtually impossible to achieve net zero logistics. Demand management must therefore be a key element in logistics decarbonisation strategies, restraining and ultimately

Table 1 Average carbon intensity of freight transport modes (UK data)

	gCO_2 per tonne-km
Bulk carrier vessel	4
Container ship	16
Freight train	25
Roll-on Roll-off ferry	51
Articulated truck	78
Rigid truck	210
Van	612
Airfreight long-haul	1128
Airfreight short-haul	2198

Source: DBEIS/DEFRA (2020)

reversing the growth of freight movement. Much of the past growth has been the result of essentially spatial processes, particularly the centralisation of production and inventory and the wider sourcing of supplies. Returning to more decentralised and localised logistics systems would help to dampen freight demand but at a relatively high carbon mitigation cost. A series of trends, such automation, 3D printing and increasing economic circularity may promote a shortening and streamlining of supply chains, reducing the freight transport intensity of economies at a global, regional and national levels. Freight demand is also partly a function of the amount of stuff that needs to be moved. This could be reduced by the adoption of more sustainable patterns of consumption, the downsizing, lightweighting and digitisation of products and avoidance of much of the current product and packaging waste. Phasing out fossil fuel will also greatly reduce the traffic in coal, oil and gas. These freight-reducing trends will be partly counteracted by other developments generating more freight traffic over the next few decades. For example, the creation of a new renewable energy infrastructure is proving both material- and transport-intensive, while adapting the built environment to the worsening effects of climate change will entail the movement of large quantities of construction material. A detailed discussion of all these trends can be found in McKinnon (2018).

(b) Shifting freight to lower-carbon transport modes.

The average carbon intensity of freight transport modes varies enormously (Table 1). Shifting freight from air to sea and from road to rail or waterways would therefore seem an obvious means of decarbonising logistics. It lies at the heart of the EU’s ‘smart and sustainable mobility’ strategy (European Commission, 2020) and the low-carbon transport plans of many national governments. At country and continental levels, however, it will require a reversal of the long-term erosion of freight traffic from rail and waterborne modes to the road network (Kaack et al., 2018). Ironically, these lower-carbon modes will also be losing much of their coal and oil traffic as a result of climate policies promoting renewable energy. In many countries, merely replacing this core traffic with alternative forms of freight will be a challenge. Rail and waterborne services, after all, will remain at a competitive disadvantage to road in terms of network accessibility, operational flexibility and transit time. Their revival as major freight modes will partly depend on the effective application of the concepts of intermodality and synchromodality, the former requiring greater investment in modal interchanges and the latter the application of new working practices, including the co-ordination of modal choice with production planning and inventory management (Dong et al., 2018). It may also need a fundamental change in managerial attitudes to modal shift. The survey of European logistics executives suggested that this change is already underway, at least in the EU. They considered modal shift to cleaner transport modes to be one of the most cost-effective of ten methods of decarbonising European logistics and strongly endorsed the priority being given by the European Commission to getting more freight onto rail.

(c) Optimising the utilisation of logistics assets.

Available data suggest that roughly one truck-km in every three or four is run empty and even laden vehicles have much under-used capacity. Across all freight transport modes, carrying capacity could be much more fully utilised to yield commercial as well as environmental benefits. Consolidation of loads in fewer trips cuts vehicle-kms, fuel consumption and emissions though can be very difficult to achieve for a variety of reasons (McKinnon, 2015). It is typically constrained by demand volatility, geographical imbalances in traffic flow, product handling characteristics, vehicle size and weight limits, a lack of information about available loads, poor co-ordination between logistics and procurement and just-in-time replenishment. Much of the blame for under-loading has been levelled at the JIT because it often involves companies sacrificing transport efficiency to minimise inventory. Relaxing this principle, however, might reduce the carbon intensity of deliveries but at the expense of higher energy consumption and emissions in warehousing and production operations.

Several other developments are promoting higher levels of vehicle fill. The digitalisation of freight transport is facilitating the online trading of freight capacity, helping carriers to find backloads and bundle consignments. More countries have been easing truck size and weight limits to permit 'high capacity transport', something that has been shown to significantly reduce CO_2 emissions per tonne-km (International Transport Forum, 2019b). Supply chain collaboration is also becoming more widespread as more companies recognise the economic and environmental benefits of sharing vehicle capacity (Cruijssen, 2020). In the longer term, the creation of a physical Internet could prove to be a decarbonising game-changer for the logistics sector. This would replicate key characteristics of the digital Internet, such as open systems, shared networking and modularisation, in the physical world of freight distribution taking asset utilisation to a much higher level than today (ALICE, 2019).

(d) Improving the energy efficiency of logistics.

The movement of freight consumes around 10% of global energy, almost all of it from fossil sources. Although the energy efficiency of all freight modes has greatly improved in recent decades, the potential exists for further improvement through a combination of technical and operational measures. Legally-binding fuel economy standards are accelerating the uptake of fuel-saving technologies in new trucks, vans and ships. In 2019, 70% of new trucks and 85% of new vans were sold in markets in which vehicle manufacturers had to meet fuel economy standards and these standards are rising (International Energy Agency, 2020b). In the EU, for example, the carbon efficiency of new trucks will have to rise by 15% between 2019 and 2025 and 30% by 2030. The Energy Transitions Commission (2019) has suggested that energy efficiency improvements of 35–40% are possible in 'heavy duty' road transport '*without radical changes in technology and potentially more with technology breakthroughs*'. In the maritime sector, the Energy Efficiency Design Index (EEDI) mandate of the International Maritime Organisation (IMO) requires new ships launched after 2025 to be at least 30% more energy efficiency than the average vessel built between 2000 and 2010 (IMO, 2021). Although not subject to similar regulations, the average energy efficiency of rail freight and air cargo operations is also projected to increase (International Energy Agency, 2019; International Civil Aviation Organisation, 2019). Technical enhancements to fuel efficiency can be supplemented by a host of operational and behavioural measures. In the trucking sector, eco-driver training combined with telematic monitoring of driving behaviour can yield average fuel savings of 5–10% (AECOM, 2016). The rescheduling of freight deliveries to off-peak periods allows vehicles to run at more fuel-efficient speeds, again offering significant carbon reductions (Holguin-Veras et al., 2018). Deceleration has also been shown to be an effective means of cutting energy consumption and emission (McKinnon, 2016). 'Slow steaming', which is now fairly pervasive across international shipping sector, was introduced primarily for commercial reasons, but has also cut CO_2 emissions by a significant margin (Acciaro and McKinnon, 2015). As the IMO's fourth Greenhouse Gas study acknowledges, '*operating speeds remain a key driver of trends in emissions and rate of emissions growth*' (Faber et al., 2020).

(e) Converting logistics to low-carbon energy.

In addition to using less energy, the logistics sector will have to switch its energy supply from fossil to renewable sources to have any prospect of reaching net zero. Broadly speaking, these alternative energy sources are either biofuel or low/zero-carbon electricity, the latter powering logistical activities directly or indirectly via batteries, green hydrogen or synthetic fuels. Biofuel, mainly in the form of biodiesel, is already extensively used in the road freight sector blended with conventional diesel. On a 'tank-to-wheel' basis, a typical 7% biodiesel blend can cut CO_{2e} emissions by around 5% (DBEIS/DEFRA, 2020). Life cycle analysis reveals, however, that on a 'well/field-to-wheel' basis, much biodiesel, particularly that derived from palm oil, emits a lot more GHG than fossil diesel (Ecofys et al., 2015). One of the few biofuels to emit substantially less GHG than fossil diesel on a life cycle basis is biomethane produced mainly by the anaerobic digestion of agricultural and food waste. Its application in the road freight sector is currently very limited, partly because supplies are scarce and relatively expensive, but also because of the high capital cost of gas vehicles and gas refuelling infrastructure. Waste material is also being used to produce biofuel with a low GHG content for jet aircraft. The use of liquid and gaseous biofuels is likely to be concentrated mainly in the aviation and shipping sectors because these modes have much less opportunity to pursue the electrification route to decarbonisation. Biomethanol and bioLNG, for example, are seen as important low-carbon fuels for ships and jatropha as the source of a kerosene substitute for aircraft.

For other sectors, electrification is the most promising option. According to the International Energy Agency (2020a), the average carbon intensity of electricity worldwide is likely to drop by a third between 2018 and 2040. Its 'sustainable development' scenario suggests that it could drop by as much as 80%. Those logistics operations already directly connected to electricity grids will see their carbon intensity reduce by a corresponding proportion, before any allowance is made for the other four categories of decarbonisation initiative discussed earlier. This includes the movement of freight on electrified rail networks. Currently, around 50% of rail tonne-kms are electrically hauled, a proportion projected to rise to two-thirds by 2050 (IEA, 2019). Warehouses, freight terminals and ports will not only benefit from their use of low-carbon grid electricity; on-site micro-generation of zero-carbon electricity by wind turbines and solar panel will reinforce their decarbonisation and in some cases, depending on the weather conditions, allow them to become carbon negative, feeding excess zero-carbon electricity into the grid.

For local deliveries by van and small rigid trucks, batteries are likely to be the dominant mode of low-carbon electrification. In Europe, small battery-operated vans already have a lower total cost of ownership (TCO) than their petrol and diesel equivalents while TCO parity for battery-powered medium/large vans is expected by 2025 (CE Delft, 2017). The choice of low-carbon powertrain for heavier, long-haul trucks in more contentious, with batteries, electrified highways and hydrogen the main candidates (plus several hybrid variants) (Energy Transitions Commission, 2019; Neuhausen et al., 2020; Shell/Deloittes, 2021). All three options have strengths and weaknesses and are likely to co-exist, but with varying shares of the road freight market in different countries. In smaller countries with shorter average haul lengths, battery-powered trucks should be able to cater for most non-urban duty cycles. Concerns about batteries being too heavy, too long to recharge and too expensive have been partly allayed in recent years by advances in battery technology and vehicle design.

Long-distance trucking operations within large countries and on international routes may justify investment in highway electrification using catenary systems such as those currently being trialled in Sweden, Germany and California (Transport and Environment, 2021). Hydrogen fuel-cell vehicles have a greater distance range and can be refuelled faster than battery vehicles can be recharged (for a given journey length). Such vehicles will only become low carbon, however, when adequate supplies of green hydrogen, produced by electrolysing water with low-carbon electricity, become available and it is uncertain when that will be. Most of the hydrogen available today is made from methane and is therefore essentially a fossil fuel. Another problem is the large amount of low-carbon electricity (around 70%) that will be lost in the electrolysis process if and when the manufacture of green hydrogen becomes mainstream (Ainalis et al., 2020).

It may be preferable, therefore, to channel the available green hydrogen—as a direct fuel, an input into a fuel cell or an ingredient in synthetic fuels—into those freight transport modes than cannot be easily electrified by batteries or cables, namely aviation and shipping. Airbus, for example, is planning to launch a zero-carbon aeroplane by 2035 powered mainly by hydrogen, which may eventually fly cargo as well as people (Potter, 2020). In the maritime sector, green ammonia, produced by combining electrolysed hydrogen with nitrogen, and e-methanol, combining this hydrogen with CO2, are being heavily promoted as future low-carbon shipping fuels (Gallucci, 2021).

5 Upskilling Management for the Decarbonisation of Logistics

This chapter has shown how the decarbonisation of logistics is a multi-disciplinary endeavour. To be able to formulate and implement a logistics decarbonisation strategy, managers need to build up their knowledge of several subject areas not on the traditional logistics and supply chain curriculum. They also need to acquire new skills and be able to liaise with specialists in fields outside the logistics domain. The recent survey of European logistics executives '*uncovered a strong desire to increase expertise in the planning and implementation of sustainable logistics'* with 30% of the respondents rating the need to increase this level of expertise as high or very high (McKinnon and Petersen, 2021).

The following is a rough checklist of the new knowledge and competences that logistics managers will need to acquire to prepare logistics for a low-carbon world:

Appreciation of the climate science: To be able to explain to staff why decarbonisation must be prioritised, to counter any climate-sceptical views and to keep carbon reduction targets well aligned with the latest scientific evidence.

Understanding of GHG emission processes: To know which GHGs originate from which logistics activities, in what quantities and with what global warming impacts. Some knowledge of the chemistry and physics of the different types of energy used in logistics is also beneficial.

Auditing of GHG emissions: To install and manage a system of logistics carbon measurement you need to be aware of the various methodologies, emission factor databases, reporting standards, software tools and data requirements of internal and external users.

Derivation of emission reduction targets: This requires familiarity with target-setting methodologies, particularly those of the Science Based Targeting initiative, and skills in modelling the combined effects of different decarbonisation measures over differing time scales.

Anticipating and complying with government climate action: As governments grapple with climate change both individually and in international alliances, many new policy initiatives will emerge. Managers will have to be able to assess the implications of these public interventions for their businesses and try to gain competitive advantage by anticipating future policy shifts.

Keeping abreast of advances in technology: To be able to identify, evaluate and exploit new carbon-saving technologies in logistics requires some knowledge of the engineering aspects of vehicle design, warehouse construction and materials handling. As digitalisation will drive much logistics decarbonisation, awareness of the potential carbon savings from logistics software innovations is also important.

Economic analysis of logistics decarbonisation options: Marginal abatement cost and internal rate of return analyses of these options will become much more common. The ability to conduct or commission these analyses and to interpret their results will become a core competence. So too will be an appreciation of the costs, benefits and risks of carbon offsetting and insetting.

Securing climate finance: The decarbonisation of logistics will be expensive and rely heavily on external sources of funding. Accessing the available green finance and securing loans and grants on competitive terms will require new skills.

Decarbonisation-related change management: Achieving deep carbon reductions quickly enough will necessitate radical changes to the planning and management of logistics processes. This will severely test the change management capabilities of the logistics profession.

Most of the discussion of net zero logistics has so far focused on technology, regulation, business practice and infrastructure. Just as important will be equipping logistics managers with the right skills and motivating them to take a leading role in the decarbonisation process.

Management Perspective on Preparing Logistics for the Low-Carbon Economy: A Practitioner's Perspective

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Five years have passed since the Paris Agreement came into force. Almost 3000 companies have committed to setting emission reduction targets in line with climate science. Increasingly, these companies are expanding their focus to also reduce 'scope 3' emissions from their supply chain, including freight transportation and logistics.

But putting this into practice is difficult. Often, multinationals outsource the transportation of their products to a third party. This makes it hard for them to have complete oversight, let alone control, over emissions. Together with the Global Logistics Emissions Council (GLEC) of companies, associations, initiatives and experts, the Smart Freight Centre developed global standardised guidelines to reach net zero emissions across the multimodal supply chain. Sustainability, logistics and procurement managers from more than 30 multinationals have already developed company-specific Sustainable Logistics Roadmaps in four steps, making use of these guidelines and the practical examples. This has required a range of competences outside the traditional managerial skill set until several years ago.

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Step 1. Where Are We Now

The exercise begins with an assessment of carbon emissions from the company's logistics system and supply chain. This requires an understanding of the emission-generating processes and an ability to calculate these baseline emissions on an accurate and consistent basis. The GLEC Framework can help to provide the necessary consistency as it is aligned with the GHG Protocol, recommended by the global disclosure programme CDP and will soon be a basis for the new ISO standard for measuring transport emissions. More than 100 companies, including HP Inc., Dow and Microsoft, have now adopted the framework, many of their managers now familiar with its structure and application.

Step 2. Where Are We Going

This involves set targets for logistics emission reductions that are in line with the Paris Agreement to limit the temperature rise to a maximum of 1.5–2.0 °C. The Science-Based Targets Initiative (SBTi) provides general guidance on how to do this, though managers must know how to tailor the target setting to their particular businesses, choosing an appropriate set of indicators and translating the emission targets into a series of actions that are practical to implement. For example, IKEA strives to make 100% of its urban deliveries by zero-emission vehicles by 2025 worldwide. P & G tracks the number of truck-km per unit of product to get fuller trucks and to use trains where possible. L'Oréal and Unilever set targets for energy efficiency and renewable energy at their warehouses.

Step 3. How Do We Get There

Companies must then decide what emission-reducing actions what for them are the most feasible and cost-effective. The European logistics platform ALICE lists these possible actions, relating to freight demand, freight modal shift, fleet asset use, energy efficiency and use of low-carbon energy sources. Assessing the suitability of these actions requires a knowledge the relevant technologies and operations as well as skills in cost accounting and change management. Guidance is available to help managers, for example in comparing the electric, hydrogen, biofuel and other energy options for freight deliveries. Managers should be capable of constructing a 'roadmap', indicating which actions are implementable and affordable over the next 3, 10 or 30 years. There are now many examples of successful logistics decarbonisation actions. For example, Trafigura uses 120 barges and 20 tugs in Colombia to move freight from a river terminal to coastal ports, reducing truck journeys and cutting GHG emissions by 24%. Dow collaborated with P & G in the U.S. to switch a portion of the company's raw material shipments from road to rail, reducing 1400 million tonnes of CO_2 emissions and 180,000

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gallons diesel per year. Henkel replaced several warehouses in Belgium with one modern warehouse in France to reduce its logistics CO_2e emissions by 39%. Heineken saved 5–15% of fuel and emissions in Asian and African countries by upgrading driving behaviour and telematics. DPDHL already delivers 33% of its own first and last mile services with clean pick-up and delivery solutions, whether by foot, electric van, e-bike or cargo bike.

Step 4. What Do We Need

Planning, resourcing and managing the decarbonisation process requires cross-functional teams equipped with broad range of skills. Minimising Scope 3 emissions also needs the support of logistics providers and other businesses across the supply chain. Setting up and managing these external collaborations presents new challenges for many businesses. As buyers of freight and logistics services, they can use tools such as the Smart Freight Procurement questionnaire during the tender process to assess suppliers on their commitment to decarbonisation and ability to deliver on that commitment. There are now numerous initiatives and organisations that can help companies individually and at a sectoral level to develop decarbonisation action plans. Many are now learning how to do this and strengthening their capability to become low-carbon logistics businesses.

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The Future of 3PLs

Carl Marcus Wallenburg and A. Michael Knemeyer

1 Introduction

We all know that it is difficult to predict what will happen tomorrow, let alone predict the future of 3PLs in the coming decade. After all, in early 2020, who could have foreseen the upheaval the COVID-19 pandemic has brought to supply chains across the globe? Faced with so much uncertainty, one may want to take the approach of many futurists who think about time in a different way. Instead of thinking in linear terms and throwing darts several years into the future, they start with identifying more highly probable events in the short term and work outward (Webb, 2019). So, while we do not own a crystal ball, we are convinced that two currently emerging aspects, you could call them trends, will shape the foreseeable future of third-party logistics providers (3PLs).

First, pronounced technological advancements pertaining to hardware and software are increasingly viewed as the future of corporate supply chain management. These advancements have entered the discussion using terms like digital transformation/digitalization and industry 4.0. They involve everything from big data analytics to the use of robotics in order to enhance supply chains and shape new business models. While over 90% of shippers view technology capabilities as a necessary element of 3PL expertise, only slightly more than 50% indicate that they are satisfied with 3PL technology capabilities (Langley, 2020). So while there is clear agreement about the importance of technology by 3PLs and their clients, expectations are still unmet.

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Second, elements and events within supply chains are getting more difficult to predict. Supply chains are faced with an environment that is undoubtedly VUCA (volatile, uncertain, complex, and ambiguous) and in which stability and order are no longer the norm. As if to prove the latter, whenever supply chain managers began feeling like things were starting to normalize during the pandemic, they were hit by new challenges. One instance was the closure of the Suez Canal in March of 2021. It sent ripple effects through the supply chains and, for example, exacerbated bottlenecks in the container shipping sector. Another instance was the war in Ukraine that started in February of 2022 and has had major impacts on supply chains not only via increased energy prices. At the same time, climate change will mandate much more substantial changes than most people expect. For example, the German government just revised its goal for carbon emission reductions; they will need to be 65 percent lower in 2030 compared to 1990.

Looking at the next five to ten years, 3PLs will need to proactively address these trends for twofold reasons: because it directly influences the 3PLs success and because it influences the 3PLs' clients' success and their associated demand for logistics services. While both trends raise challenges for 3PLs, they also offer ample opportunities for 3PLs by enhancing their current services as well as developing new offerings. While many clients of 3PLs were adversely affected by the COVID-19 pandemic (see, for example, many bankruptcies of US retailers in 2020), 3PLs themselves often benefitted from 2020's turmoil. For example, the three largest 3PLs in the world per Armstrong and Associates (2021b) (i.e., DHL, Kühne +Nagel, and DB Schenker) in 2020 all reported growth in their profitability between 10 and 32 percent compared to the prior year.

To outline the future of 3PLs, this chapter is organized as follows. After this introduction, the underlying understanding of 3PLs and their competitive landscape is outlined. After that, the impact of technological advancements on 3PLs is detailed. This will include a discussion of robotics, automation, and digitalization. Next, a description of the VUCA environment facing 3PLs and their clients is established. The chapter concludes with the identification of leadership and management skills that will need to be a point of emphasis within the future 3PL workforce to address the VUCA environment.

2 What Is a 3PL?

Before outlining the future of 3PLs, it is important to establish a common understanding of what actually constitutes a 3PL. The term "third-party logistics provider" has been around for over 40 years. It first arose when transportation contracts started to involve more than shippers and carriers as the two classic parties. Today, 3PLs typically offer bundles of integrated logistics services that extend beyond pure transportation and may especially involve warehousing, packaging, and value-added services. As such, e-commerce fulfillment has also become a notable segment of 3PLs' business.

A 3PL is part of the extended supply chain as it does not take ownership of the shipped or stored products. Instead, 3PL are key facilitators of supply chains by taking responsibility for organizing (and potentially carrying out) logistics activities on behalf of their commercial clients. This means that some 3PLs serve as pure intermediaries while other also own assets like trucks and warehouses. Correspondingly, Armstrong and Associates (2021a) distinguish four market segments, which may be further broken down by client industries:

- **Dedicated Contract Carriage:** In this segment, the 3PL supplies its client with access to a trucking fleet in combination with the necessary fleet management.
- **Domestic Transportation Management:** In this segment, the 3PL provides value-added transportation management services in specific regions (i.e., within North America or China).
- **International Transportation Management:** This segment is conceptually very similar to the Domestic Transportation Management segment. In practice, however, it is made up of different 3PLs as this segment typically involves the use of a wider variety of modal options than domestic transportation (i.e., air, road, sea) and deals with more complex tasks related to taxes and duties as well as the legislation of multiple countries. Therefore, this segment sees fewer mid-sized 3PLs and more large, international 3PLs, as well as small players, specialized in a specific niche (e.g., road transportation between Germany and the UK accounting for all challenges posed by Brexit).
- **Value-Added Warehousing and Distribution:** In this segment, 3PLs offer inbound and outbound warehousing solutions to their clients. These are often combined with value-added services like packaging or even assembly steps and inbound or outbound transportation. As such, this segment, for example, includes e-commerce activities, where a 3PL handles the fulfillment of the online sales of its client. Another example of this segment is returns operations, which have grown along with increased levels of e-commerce.

The literature offers an abundance of reasons why clients use 3PLs. Of these, we want to highlight a few that are central to understanding the future of 3PLs. First, 3PLs offer efficiency gains in carrying out logistics activities and in handling high complexity within supply chains. Especially, the latter facilitates outsourcing (i.e., the use of outside resources). Second, by providing access to outside resources, 3PLs are key elements in providing both dynamic (i.e., short-term operational) and structural (i.e., mid- to long-term strategic) flexibility (Christopher & Holweg, 2011) to their clients. Third, because 3PLs serve multiple clients, they can offer access to solutions and technologies beyond what would be economically viable for the single client—especially when the client is not a large multinational corporation. Fourth, each client can also profit from a portfolio effect; serving many clients allows 3PLs to reduce the volatility and the uncertainty by pooling the demand of different clients. That is, for example, the case when a 3PL is active in a less-than-truckload cargo network, secures long-term capacity on container shipping lines, or operates shared warehouses.

3 The Current Competitive Landscape of 3PLs

The 3PL market is highly competitive and fragmented. Based on data from Armstrong and Associates (2021b) and Mordor Intelligence (2021), the global market share of the largest 3PL (DHL) can be calculated to be around 2.8 percent, and the 50 largest 3PLs combine to slightly less than 34 percent of the global market.

As a result, many large companies are actively acquiring other market players or forming alliances with smaller companies to extend their presence in specific regions or market segments. Still, the three largest players in the market, DHL Supply Chain & Global Forwarding, Kühne + Nagel, and DB Schenker, today have a smaller market share than a decade ago. This has been caused by the strong growth of the global market and the entry of many new players.

Even smaller 3PLs are active in forming alliances with other 3PLs, as a series of studies by Wallenburg and colleagues shows (e.g., Schmoltzi & Wallenburg, 2011; Raue & Wallenburg, 2013). More than half of 3PLs are active in at least one alliance, typically tied to road transportation. These alliances relate both to the operations and complementary activities like sourcing and marketing/sales and are driven by the aim to improve the service quality and protect or even enhance the market share (Schmoltzi & Wallenburg, 2011).

4 Impact of Technological Advancements

Advancements in digital technologies are providing both challenges and opportunities for 3PLs. Technologies such as artificial intelligence (AI), robotics, drones, internet-of-things, augmented reality, and blockchain are providing 3PLs the ability to increase the responsiveness and speed of their operations, enhance their integration with their clients and other members of the supply chain, improving dynamic decision-making with real-time information as well as improving resilience through more proactive data-driven modeling. In short, technological advancements usually referred to via terms like digital transformation, digitalization, and industry 4.0 are going to continue to dramatically shape the future of 3PLs (PWC, 2021). According to the DHL (2020) logistics trend radar, for SCM the most impactful will be Robotics and automation, big data and AI, cloud and application programming interface (API) as well as IoT. As such, we will highlight these particular technological advancements.

4.1 Robotics and Automation

The warehousing segment of the 3PL market has not been at the forefront of adopting new technologies. As the comprehensive report by Gutelius and Theodore (2019) outlines, over the last two decades, the focus of technological innovation was on eliminating data entry (e.g., through improved scanners) and reducing the amount of walking as part of warehouse workers’ activities (e.g., through conveyor systems).

The main reason for 3PLs' reluctance to invest more in developing and utilizing robot technologies can be seen in the cost-based, risk-averse competitive dynamics that have led 3PL to reduce their exposure to fixed costs wherever possible (Gutelius & Theodore, 2019). Instead of investing in technologies that used to have relatively long payback periods (according to Harris et al., 2018 on average more than five years in 2010) compared to the relatively short duration of contracts with warehousing clients, 3PLs rather focused on incrementally optimizing (i.e., streamlining) existing processes. However, both 3PLs and their clients recognize the importance of increased adoption of automation for success (Langley, 2020).

The newest developments can be seen in the field of automated mobile robots (AMRs). Such robots can be used for moving material from storage areas to fulfillment zones (e.g., the well-known Kiva solution used by Amazon). Part of their popularity is that they can be operated with little or no variation to the existing warehouse infrastructure. Besides, AMRs can also be used for the picking and packing process. Their benefits lie in increasing efficiency, alleviating worker shortage, and addressing regulatory work restrictions (e.g., limitations at nighttime or prohibited Sunday working).

The overall situation for increased usage of robotics in 3PL warehouse operations is relatively favorable:

1. 3PLs are exposed to a shortage of workers;
2. According to the Muro et al. (2019) data, between 35 and 80 percent of tasks in warehouses are susceptible to automation;
3. Most warehouse workers work in large warehouses. For example, in the US, 73 percent are employed in warehouses with more than 100 workers (Gutelius & Theodore, 2019);
4. The payback period has dramatically dropped and is in many cases only 12 to 24 months; and.
5. Technology providers offer robotics as a service (RaaS) where 3PLs can implement and use robots without high fixed costs.

While Gutelius and Theodore (2019) conclude that the penetration of robotics will remain low over the next 5 to 10 years and will be limited to the large players in the market, we do not agree with this view because of the very short payback periods. However, the key to realizing the potential benefits offered by robotics is using flexible solutions that can be easily adapted to changing contexts. Examples of this would include robotics that can be used for multiple clients in a shared warehouse. Another example would be partnering with a 3PL that serves a broad range of clients and, therefore, allows the provider to scale the number of used robots up and down in any given warehouse depending on specific seasonality and operational load. With the RaaS-models offered, 3PLs should move away from viewing robotics as fixed investments for a single client and instead demand the same flexibility from their technology providers that the 3PLs' clients demand from them in the transportation sector. No 3PL client would ever accept a situation where they were limited to contracting a fixed trucking capacity on fixed routes for every day of the year.

4.2 Digitalization

According to both DHL (2020) and Kuehne+Nagel (2021), big data analytics, AI as well as cloud-based application services and APIs are four technological trends that will have a high impact on the 3PL industry in the foreseeable future.

Cloud and APIs belong within the category that Wang and Sarkis (2021) call connecting (i.e., technologies that facilitate interconnections among supply chain actors). They allow 3PLs to integrate and scale software services both across their clients and across the carriers that they are utilizing, in many cases replacing the need for client-specific electronic data interchange (EDI) solutions.

Cloud-based solutions allow 3PLs to minimize capital expenditures and fixed costs while being able to coordinate all activities based on one integrated view across all elements of transportation and warehousing. This relates both to the macro-level and the micro-level of individual trucks, workers, smart glasses, or robots. Another advantage of the cloud is its elastic nature, where the individual 3PL always has the computing power it needs while only paying for the resources they utilize. Moreover, it offers flexibility and reduced entry barriers for small- and medium-sized 3PLs.

In this respect, APIs can be seen as the "glue" that ensures seamless data transfer (DHL, 2020). APIs are software protocols that allow applications to communicate and exchange data. In contrast to EDIs, they are standardized and allow 3PLs to integrate, for example, delivery options, fulfillment services, and cargo rates in webshops, e-commerce platforms, and logistics marketplaces (DHL, 2020). The integrative use of APIs and the cloud enables fast, cost-effective, and flexible digital connectivity, which supports achieving end-to-end real-time visibility beyond a focal firm's boundaries (Wang & Sarkis, 2021). Through this, 3PLs can create considerable value for their clients.

Big Data Analytics and AI both belong to the capitalizing category of Wang and Sarkis (2021) by creating additional value for supply chain actors. They offer potential benefits across all services that 3PLs offer to their clients. The DHL (2021) trend radar sees big data analytics as "part of the de-facto operating model for the logistics industry." It allows using the abundance of data to better predict what will happen and proactively prescribe how to best deal with this. It enables a 3PL to substantially increase their operational efficiency by using real-time data to staff warehouses, choosing the best picking routes, and even optimizing service levels across clients that are served by the same operations (e.g., in a shared warehouse). In transportation, for example, it supports the optimal repositioning of truck capacity, but also the optimal quotation based on the positioning of all sea freight vessels across the globe. However, big data analytics also support offering enhanced or new services and create new business models. At the same time, the growing computing power has fueled the rapid development of AI, which offers diverse possibilities. Across the supply chain activities, we experience reduced manual handling and increased automation based on AI-facilitated autonomous guided vehicles to move goods and robots for specific tasks such as picking, sorting, and packing (Wang & Sarkis, 2021).

To fully capitalize on the technological advancements, 3PLs need an open-minded culture that views change as the new norm in combination with a client-centric perspective that continuously questions what would provide value to the potential clients (Cichosz et al., 2020). In addition, especially small and medium 3PLs need to rely on partnerships with technology providers but also with other 3PLs to build the capabilities necessary to compete with larger 3PLs.

5 Impact of the VUCA Environment

A second trend affecting the 3PL industry and the supply chains they manage is the increasingly VUCA (volatile, uncertain, complex, and ambiguous) environment in which they operate. This type of environment poses substantial challenges to how 3PLs work and their ability to meet rising client expectations. At the same time, it offers great opportunities for 3PLs as well as their (potential) clients who are also operating in this VUCA environment. The inherent challenges of this type of operating environment will motivate companies to not only seek out experts in providing logistics services but also 3PLs who are able to help them respond to the disruptions and changes that will occur in the coming years.

In a *Volatile* situation, supply chains are marked by change; the clients will be unsure when the situation might arise or how long it might last. This calls for adding slack in areas such as inventory and/or workforce to be prepared to address unforeseen negative events. 3PLs may be able to provide this slack for their clients in a more economical manner due to the risk pooling abilities described earlier in the chapter. While it is not in the DNA of 3PLs to inefficiently carry excess capacity, they may be able to find naturally occurring slack in the operations of some of their clients at times of need for others. This will naturally rely on the visibility and flexibility provided by some of the technology discussed previously.

The root causes of *Uncertain* situations are typically easy to understand, but potential changes are unsure, their probability unclear. Thus, clients will turn to their 3PLs for the collection and interpretation of data to clarify the issue. 3PL expertise, access to and ability to process logistics information should enable them to provide a path for their clients to reduce operating uncertainty. Enabled by increased abilities to access and utilize not only their own operational data, but that of their clients and supply chain partners, 3PLs who make investments in advanced technologies and associated worker skill sets will be poised to gain business in the future.

Complex situations arise due to the interconnectedness of most corporate supply chains across the globe. The differences in regulatory environments, changing tariff structures, and the challenges of managing across cultures are just a few of the examples where clients will lean on their 3PLs for the expertise required to address rising levels of complexity. Larger 3PLs should be able to leverage their understanding of global trade to identify and form relationships with smaller local and regional providers. A 3PLs ability to operate on a global scale with local knowledge should provide much-desired relief for clients facing these complexities. Both large and small 3PLs will need to increasingly leverage collaborative relationships in order to form these ecosystems for their clients.

Finally, *Ambiguous* situations involve unclear causal relationships and events that are viewed as "unknown unknowns." While some events may be completely new, others may merely be new for a given supply chain (Gao et al., 2021). This favors 3PLs that can transfer knowledge that they have gained in relationships with other clients operating different types of supply chains. As a result, the accumulated experiences could be transferred across clients to enable them to better deal with their "unknown unknowns."

Such a VUCA environment requires companies to invest in both proactive and reactive capabilities (Wieland & Wallenburg, 2012). Corresponding strategies have been discussed using terms like robustness (Wieland & Wallenburg, 2012), resilience (Wieland & Durach, 2021), and plasticity (Zinn & Goldsby, 2019). As we will outline in the following, 3PLs are in an ideal position to support their clients concerning all four of these strategies, primarily because each of them can pool risks across clients, possesses an intimate knowledge of a broad array of client supply chains, and has the capability to scale resources up and down and quickly access resources by creating new interconnections.

The ability of 3PLs to offer robust solutions that are able to withstand disruptions has long been known. Regarding resilience, it is necessary to distinguish the traditional supply chain perspective on resilience—you can term this engineering resilience—from a newer perspective termed socio-ecological resilience (Wieland & Durach, 2021). Both robustness and engineering resilience (i.e., the ability to quickly, after a disruption, bounce back and return to the initial equilibrium state) are facilitated by the 3PL's access to a broad network of multiple carriers and multiple transportation modes. In addition, 3PL can cater to fluctuations by providing generic resources that are non-specific to the individual client. And as the level of VUCA will increase in the foreseeable future, so will the business opportunities that this environment will provide to 3PLs.

Socio-ecological resilience (Wieland & Durach, 2021) and plasticity (Zinn & Goldsby, 2019) are two concepts that are not completely disjunct. The former refers to the ability to learn after a disturbance and bounce forward to a new equilibrium state (Wieland & Durach, 2021) or, as Walker (2020, p.11) phrases it: "Resilience is, in fact, the ability to adapt and change, to reorganize, while coping with disturbance. It is all about changing in order not to be changed," which requires the organization to experiment and be open to change.

Supply chain plasticity extends this perspective and refers to the "capability to rapidly make major changes to a supply chain in order to respond to or to drive changes in the environment" (Zinn & Goldsby, 2019, p. 184). The pandemic is a recent example where companies were required to move outside their operational comfort zones to redesign a new state. To reach this new state, companies will be looking to their 3PLs to enhance their abilities to implement what can be referred to as a plastic response.

Supply chain plasticity will involve a 3PL assisting its client in a significant redesign in response to a disruption in their operating environment (Zinn & Goldsby, 2019). Plastic responses to disruptions, such as the pandemic, differ from typical efforts to restore the supply chain to its pre-disruption state. Instead, the focus is on acquiring the new skills, making required investments in new assets, and forming the new supply chain relationships needed for a significantly redesigned supply chain. 3PLs will increasingly be called upon to provide these skills and assets and facilitate the connectivity required to establish new relationships. This will require 3PLs to become better at working across their typical vertical lines of business and their tendency to focus on countries and regions. The 3PL of the future will need to become experts in experimentation to quickly identify innovative ways for their clients to move effectively into new operating models due to the pressing needs brought on by ambiguous situations.

The key for 3PLs to realize the above opportunities is not only to be proficient in managing the logistics activities assigned to them by their clients but also to better manage the relationships to the clients. Only when developing deep knowledge about both the client's current supply chain and strategies will the 3PL be able to provide the highest level of adaptation that tomorrow's client will be looking for (Johne & Wallenburg, 2021).

6 Leadership and Management Skills for a Successful Future

Facing pronounced changes in the upcoming decade brought on by the VUCA environment, 3PLs will look to their corporate leadership to ensure success. The C-suite needs to monitor trends, seize technological opportunities and translate them into business opportunities (Cichosz et al., 2020). Moreover, the leadership team needs to shape an organizational culture that is open to experimenting and change. Making mistakes should not be seen as a blemish as failing fast is an opportunity for learning and improvement.

In addition, establishing and managing collaborative relationships will be a second key factor for 3PL future success. 3PLs have been consistently called upon to manage logistics and supply chain activities for their clients. Moving into the future, 3PL managers will need to develop and utilize new skill sets to meet the constantly evolving expectations of their clients in VUCA environments. In particular, the three Cs of Credibility, Choreography, and Consumer-Centricity will become foundational skills for logistics and supply chain managers moving forward. Each of these skill sets will enhance the ability of the 3PL manager to drive value co-creation activities for their clients.

To move beyond being a transaction, 3PL managers will need to develop an ability to establish a working environment where their company is seen as indispensable to their clients. This requires the formation of 3PL credibility. Credibility with clients comes from the development of five key behaviors (1) elimination of blame, (2) telling sticky stories, (3) moving beyond just being the bearers of bad news, (4) increasingly saying yes, and (5) asking what if (Brockhaus et al., 2019). To eliminate the blame game, 3PL managers must do everything in their power to deliver on the promises they make to their clients. This requires a clear understanding of both the client's needs and the capabilities of their own organization. Increasingly, this understanding will be grounded in the data flowing across the supply chain. Failing to calibrate between these two will lead to more excuses than co-creation of value. If the 3PL is unable to deliver on a promised cost reduction or service enhancement, trust is lost. Without trust, the 3PL will not be given opportunities to expand into new value creation areas. The 3PLs offerings will be commoditized and be increasingly seen as replaceable.

The ability to speak your client's language is key for telling clients stories that stick. 3PL managers need to clearly articulate the operational aspects of their client's operations, but in a way that speaks to P&L impacts of these activities. Building the skills to talk in financial terms will be key. Speaking in the language of CFOs will enable 3PL managers to gain access to the financial support and commitment to implement desired changes or experiments. These conversations may also require the 3PL manager to explain how lack of transportation capacity or warehouse labor shortages will ultimately affect their clients' P&L. Developing the skills to speak about the numbers will be critical. Without the ability to understand and communicate the numbers, it will just be viewed as an opinion.

Clients typically hear from 3PLs when something has gone wrong. Instead of always focusing on how they are addressing the problem of the day, 3PL managers must improve their abilities to uncover unanticipated value and bring these opportunities to their clients. By gaining comfort in the use of technologies such as big data and artificial intelligence, 3PL managers should be able to increasingly uncover insights that can enhance their clients' operations. While not all 3PL managers will need to be data scientists, they all will need to be able to communicate with these data scientists to define problems and proactively communicate technology-enabled solutions for their clients. 3PL managers need to be the bearers of good news from time to time.

3PL managers need to learn the art of possible. Rather than coming with prepackaged solutions to clients' problems or arguments for why certain things are not possible, 3PL managers will need to bring creative problem-solving skills that allow them to respond, "yes, we can do that, now let's discuss what that means." Providing alternatives with data-supported analysis of the various trade-offs will enable the type of customized solutions that clients will increasingly demand.

Finally, 3PL managers must develop the ability to anticipate the needs of their clients and offer insights on emerging ways of operating their business. The 3PL manager of tomorrow will be skilled in constantly asking "what if?" concerning their client's business. These "what if?" questions will be followed up by structured experimentation to see potential results of the changes. 3PL managers will need to become skilled at running structured and controlled experiments that provide actionable insights for their client's operations.

Once a climate of 3PL credibility is established, the 3PL manager of the future will need to leverage choreography skills in support of value creation for their clients (Fawcett et al., 2020). In the past, many 3PL managers have complained that (1) they "have no visibility into the details of their clients' strategies," (2) they "lack the resources and discipline to manage client complexity," and (3) they are "not very good at looking too far down the road and 'crystal balling' the future." These phenomena exist because of the 3PL manager's inability to choreograph "coordinated action" across geography and time in a VUCA environment. That is, 3PL managers have struggled to effectively select the right actors, engage them to act in new and evolving roles, and then provide the direction, discipline, and autonomy to perform (i.e., execute, experiment, and improvise together). This higher level of engagement is critical to delivering client outcomes even when the unexpected happens. Choreographic skills will require 3PL managers to see more possibilities for their clients, expand joint capabilities by leveraging talent in new ways, work with the client to create a shared vision for the engagement, encourage and inspire experimentation internally and with the client, and connect the various resources across both organizations to co-create value.

A final skill that will be important for 3PL managers to develop moving forward is the ability to think in terms of consumer centricity (Esper et al., 2020). The social and technological changes in the past 20 years, coupled with the effects of the pandemic, have created the need to reinvigorate a focus on how the supply chain can influence consumer experiences. These experiences involve issues such as increasing levels of online shopping, delivery to the home, consumer expectations of availability and visibility, and consumer values concerning supply chain activities influencing purchasing decisions. Consumer issues have become so vital that they must be central to how supply chains are designed and managed moving forward. This is even true for firms that reside further upstream. Thus, the need for 3PL managers to become more versed in the activities of the ultimate consumer that sits at the end of the supply chains they help manage. A consumer-centric supply chain requires 3PL managers to focus on the relationships with their immediate clients and suppliers and appreciate consumer behaviors, perspectives, and values. The need for a duality of focus, both on the focal client and the consumers that rest further downstream, will place new demands on 3PL managers.

7 Conclusions

Two trends will shape the foreseeable future of 3PLs. First, technological advancements concerning hardware and software (i.e., new digital technologies) are a cornerstone of future supply chains. Second, events are getting more difficult to predict as supply chains are faced with an environment that is getting increasingly VUCA (volatile, uncertain, complex, and ambiguous).

Looking at the next five to ten years, 3PLs will need to proactively address these trends for twofold reasons: because it directly influences the 3PLs success and because it influences the 3PLs' clients' success and their associated demand for logistics services. While both trends raise challenges for 3PLs, they also offer ample opportunities for 3PLs by enhancing their current services and developing new offerings.

For this, 3PLs need to enhance their leadership and management skills. The leadership teams should shape an organizational culture that is open to experimenting and change, where mistakes are not a blemish but seen as an opportunity for learning and improvement. Moreover, 3PL need to emphasize establishing and managing collaborative relationships. Especially credibility, choreography, and consumer-centricity will become key skills moving forward as each of them enhances the ability to drive value co-creation activities with the clients.

Management Perspective on Contributing to the Companies That Move the World

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What does it take to keep the world moving through significant disruption or a crisis?

For many people, this is a rhetorical question; however, for those of us in the global transport and logistics industry—this is a question that helps to shape what we do every day.

Over the past 30 years, working for different multinational organizations in the logistics sector, I have observed that effective leadership is fundamental to meeting the challenges of growth and adaptation. Our industry works across many borders, with diverse challenges presented by multiple cultures, customs, laws, and ways of doing business. Ultimately, it is the people running our business that enable the organization to rise to the occasion and deliver.

In the global battle for talent, it is incumbent on our industry to attract the best and brightest leaders and talent to our sector. As technology and innovation brings companies closer to their end consumers, digitally or physically, our current and future logistics leaders need to keep a step ahead of market trends and anticipate the coming needs of our customers.

So, what do future leaders need to bring to third-party logistics (3PL) providers?

While individuals have diverse leadership styles, there are some key themes that capture the essence of leadership in our sector:

- Developing **strategic enterprise leadership**;
- Defining and setting the organization's **culture**;
- Driving a **customer-first mindset**;
- Ensuring a **progress mindset** in a fast-paced industry that embraces innovation, agility, technology, analytics and digitization; and.
- Providing effective **leadership through change**.

(continued)

Employers consciously need to develop and deliver their culture, purpose and values to drive the future; and leaders play a key role in setting this agenda. These elements, in turn, set the tone for the value proposition of the business and industry to the next generation of employees who are considering a future in logistics as against other industries.

As they say, employees join a company for its brand and stay (or leave) for their leader. In today's unpredictable, pandemic-affected world, the role of a leader is even more critical. Besides setting the direction, they are expected to drive an empowering culture that can get the best out of individual team members. At the Toll Group, the expectations of people leadership are as follows:

1. **Be *Visible*** and present to their teams and the organization—often and regularly. Lead from the front.
2. ***Communicate*** regularly with their teams. Share what's going on, the future direction, the outcomes; and listen to what they have to say, so they are in tune and touch with ground realities.
3. ***Execute***—deliver on their objectives and thus set an example for others to do the same.
4. Consciously ***develop*** people in their teams, including giving them ongoing constructive and positive feedback;
5. ***Recognize*** people, both, in their teams and across the organization. Acknowledge good work, good behavior, and good values, so as to encourage it.
6. ***Inspire*** and infuse ***positive energy*** into their teams and the organization, while still being realistic (and not just a cheerleader); and.
7. Show ***empathy***, in balance. Be human and authentic. They are, after all, no different to others.

These elements (and more), collectively, inspire and drive an employees' decision to stay or leave a company. The biggest common influencing factor behind employees joining, staying, remaining inspired, engaged and driven, and going above and beyond is the leader herself or himself.

That is why the role leaders play in a business is so critical. . . and cannot be taken lightly.

That said, on a separate note, I encourage the future generation of leaders and employees to seriously consider a career in the transport, logistics, and the 3PL industry. Our sector is at the forefront of global trade as we connect clients and customers across the world. The past few years have shown that regardless of the changes in the industry, be it via digitalization, automation, or even a pandemic-impacted environment, ours is an industry that "delivers" regardless of the challenges.

(continued)

If nothing else, the community has realized that the logistics industry is what really makes the world go round, and leaders and employees who can deal with the ambiguity and change in this fast-paced industry bring in a unique breed of capability that can be relied on to make a difference anywhere and anytime.

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Air Cargo Logistics: The Dawning of a Golden Decade?

Rico Merkert

1 Introduction

Air cargo carriers have traditionally been loss making volatile businesses, not least because of substantial government intervention, inherent business model flaws, ever declining yields, and the lack of a level playing field in the sector (Merkert et al., 2017). This has, in many cases, led to air cargo divisions of combination carriers such as Lufthansa, Qantas, or Singapore Airlines being neglected and often disadvantaged through unfavorable joint-cost allocation practices within those airline groups (Morrell & Klein, 2020), exacerbating the financial weakness of the cargo arms of such carriers (Reis & Silva, 2016). With COVID-19 hitting the aviation sector hard and concerns around the carbon footprint of aviation rising (Gössling, 2020), some commentators have been wondering whether the air freight industry will ever return to commercial viability and whether it may indeed have a future (de Rugy & Leff, 2020). No longer is it just cargo airlines who are seen as financially volatile but due to the pandemic and resulting high debt, dwindling asset values and a broken business model it is now also full-service carriers who are at risk, as they are overly reliant on high yielding premium passenger traffic (CAPA, 2020). This is problematic for air cargo, as those combination carriers typically carry substantial freight volumes in the belly-hold of their passenger aircraft (e.g., Merkert and Ploix, 2014). As a result, cost transformation and automation (i.e., non-contact delivery) programs have been implemented at many air cargo logistics businesses, putting pressure on jobs not just on the demand but also on the supply side.

As such, many students and early career practitioners have asked throughout 2020 and early 2021, whether there is any potential for a career in air cargo, and if so, what skills will be required to survive in an increasingly competitive and challenging

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future. This chapter attempts to provide answers to that question by first describing the industry and the business models it comprises. We then analyze the current (much brighter than first anticipated) situation and provide an outlook for the sector, which could potentially be the golden decade for air cargo logistics. That outlook is based on a discussion of challenges and opportunities presented to the various players in the air freight industry, such as technological advancement and sustainability expectations. We finally outline the key trends in resulting skill sets that, in our view, will be required by logistics and supply chain professionals (i.e., recent graduates) navigating the challenges and opportunities of an evolving landscape. These will form the foundation for a successful career in the "new normal" of air cargo logistics.

2 The Post-COVID-19 Air Cargo Business "New Normal": Booming e-Commerce and Disruptions Galore?

Before providing an outlook to what the air cargo logistics sector may look like in the future, this section is an attempt to take stock to assess what has happened since the beginning of the pandemic and to portray what is currently described to be the "new normal" for the air cargo business. While it has been shown that air cargo is resilient to exogenous shocks such as the global financial crisis (Alexander & Merkert, 2021), few predicted that COVID-19 would result in the sectors' strong financial performance during the pandemic and hence a resulting potential decade of opportunities. As shown in Fig. 1, air cargo volumes have deteriorated immediately

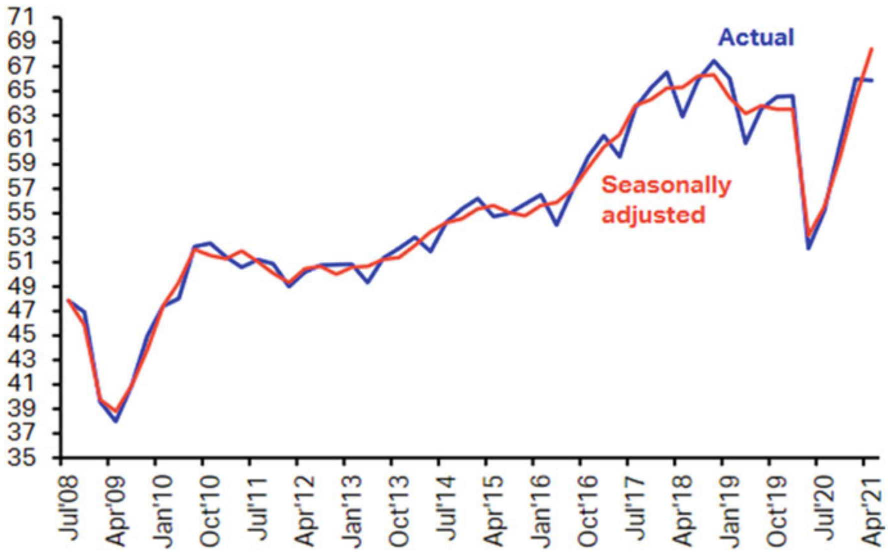

Fig. 1 Industry-wide Capacity in Cargo Ton Kilometers (bn per rolling 3 m period). Source: IATA

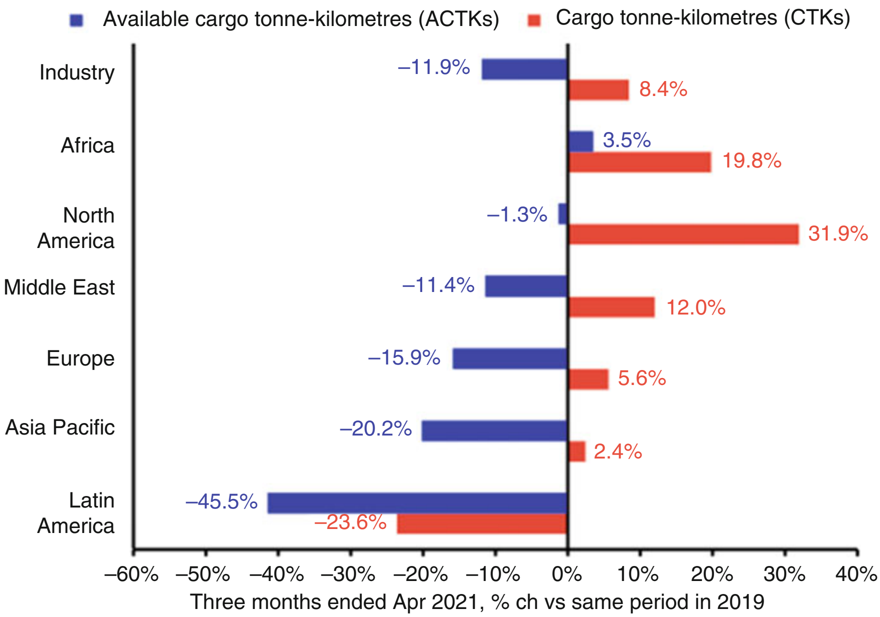

Fig. 2 Global air cargo capacity and output. Source: IATA Economics

after the initial COVID-19 shock but then experienced a V-shaped quick recovery, similar to that following the global financial crisis that ended in early 2009.

Different to previous global shocks, the COVID-19 crisis and related travel restrictions (e.g., border closures) have resulted in a very significant decline in belly-hold capacity in passenger aircraft, while dedicated freighter capacity has increased by up to 20–30% on a monthly basis in 2020/21 compared to 2019. While at the global level, the total air cargo capacity had decreased (due to the loss of belly-hold capacity in passenger aircraft), it became apparent (in the data but also to the media and our students) that global supply and value chains are the backbones of many industries and economies, as contrary to capacity, global air cargo demand, and output increased during the pandemic, as shown in Fig. 2. This was most evident in North America but also in all other regions par Latin America.

It can be argued that air cargo did benefit from the need of global supply chains to continue to function, the increased demand for urgent delivery of medical and personal protective equipment that could not be delivered on time by the shipping industry, the boom in e-commerce and from increasingly congested container ocean shipping supply chains. With capacity decreasing and demand or output increasing at the same time, the industry experienced higher air cargo load factors than pre-COVID-19 and also much higher air cargo yields, as shown in Fig. 3.

This has resulted in air cargo operators becoming financially more viable and also for air cargo to become much more competitive against ocean shipping lines not only in terms of relative rates but also in terms of perceived value. However, this is not

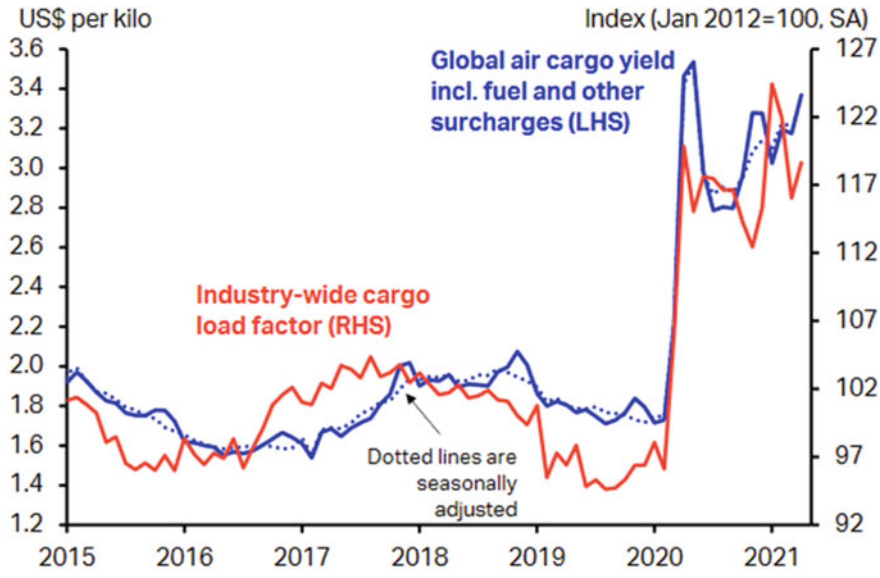

Fig. 3 Global air cargo yields and load factors. Source: IATA

something all air cargo players in all jurisdictions have been able to convert into higher profit margins equally. It also does not tell us what is going to happen in the future. What we have seen for most operators is that cash is king, which as a strategy is not forward looking but more a means of surviving. It is very likely that volatilities are going to stay with us, and as such, it is clear that agility will be a strength that will not only form firm competitive advantage but will also be a personal capability of value to air cargo players. What is also sought after is leadership and strategic foresight. Whilst not all air cargo players have generated high profit margins, for many the pandemic has let to substantial profits and they are now asking themselves how to put those funds into good use. Should they purchase new freighter, invest in new technology or push digital transformation or just sit on this cash as a war chest for what may come next? In other words, is what strategists foresee next going to be another volatility event or perhaps the dawn of a golden decade for the air cargo supply chain industry?

In terms of early indications of what the future or "new normal" may look like, it appears that in most jurisdictions high value express shipments (e-commerce) have weathered the storm particularly well, followed by trucked cargo, as shown exemplary for the Chinese market in Fig. 4. International air cargo has had some good months but is much more volatile and often highly dependent on international passenger air services, which have suffered unprecedentedly and will take much longer to recover, if ever fully. As such, it is worthwhile looking at the different air cargo business models to gain a better understanding around which of those may hold the future for this sector, including career and employment opportunities.

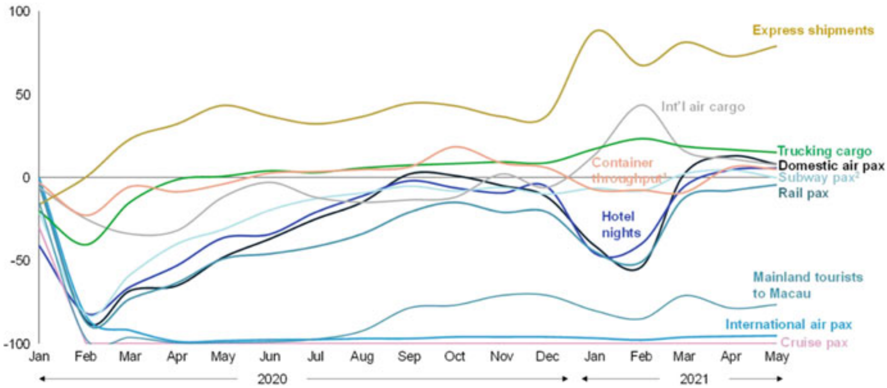

Fig. 4 Recovery rate by travel and logistics subsectors in Mainland China (change over 2019, percent). Source: McKinsey & Company

3 New Players and New Business Models

As outlined in the previous section, air cargo as the long forgotten and neglected child of combination carriers has recently experienced a revival, as COVID-19 has identified the reliance of global supply chains and entire economies on the functioning of air cargo logistics. Before the pandemic, air cargo typically used to be loss making (Alexander & Merkert, 2017; Morrell & Klein, 2020) with for example Cargolux as one of the leading pure cargo operators having chronical financial issues and repeatedly requiring government support. That very same airline achieved record results in 2020 with an EBIT margin of 31.3% (Cargolux, 2021) and 2021 is on track to be even more profitable due to air freight now being even busier and e-commerce booming even more.

Unsurprisingly, this has resulted in new players entering the market and novel business models being adopted. Especially, the e-commerce boom combined with the lockdowns in many jurisdictions have accelerated the trend of air cargo becoming increasingly a door-to-door affair (Merkert & Bushell, 2021). While all air cargo business models, as summarized in Table 1, recovered quickly from the early COVID-19 demand shock and experienced an increase in profitability, going forward some may be better equipped for growth.

For example, all-cargo carriers did benefit more during the first phase of the COVID-19 pandemic due to the sudden demand for personal protective (PPE) and medical equipment shipments and them having dedicated freighters available. This advantage was amplified by belly-hold capacity of combination carriers being substantially reduced or removed entirely due to travel restrictions and border closures grounding large parts of the global passenger aircraft fleet. As a result, all-cargo carriers have not only been highly profitable during the pandemic, but new

Table 1 Prominent air cargo business models

Corporate objectives	Passenger/Cargo Operations		Cargo Operations		
	Belly	Belly flex/combination	All-cargo	ACMI/ charter	Integrators/express
Cargo strategy	Value cargo as an important by-product of the core passenger business.	View freighters to capture high market shares of core routes, leveraging belly-hold network.	Airport-to-airport transport of cargo is the primary business task.	Airport-to-airport demand (and matching supply) is the primary business task.	Primarily provide express network capacity for premium air cargo products.
Customer marketing strategy	Freight forwarders, some shippers, government mail contracts.	Freight forwarders, shippers, government, other airlines, and integrators.	Freight forwarders, shippers, government, other airlines, and integrators.	Some freight forwarders, government, other airlines, integrators.	Mainly direct shippers.
Network design strategy	Centered around passenger gateway airports, mix of long-, medium-, and short-haul routes. Typically, member of an airline alliance.	Similar to belly carriers, use of freighters as supplement on high-density routes. Some cargo only destinations.	Cargo focused, including multi-leg or asymmetrical stages.	No network. Routings are determined by clients.	Hub and spoke, with distribution centers for sortation and processing.
Capacity management strategy	Residual belly-hold capacity.	Combination of passenger and freighter aircraft.	Dedicated freighter fleet.	Leasing of aircraft on short- and long-term basis.	Cargo aircraft as a link in door-to-door services.
Examples	Japan Airlines, Delta, American, Air Canada, Air India	Qatar, Air China, China Southern, Air France-KLM Cathay, Qantas, Lufthansa, IAG, Korean, Emirates, Singapore	Cargolux, China Cargo, Air Bridge Cargo, Nippon Cargo, Polar Air Cargo, AirBridgeCargo, Cargojet, Avianca Cargo	Atlas Air, Volga-Dnepr Airline, ATI, Kalitta Air; SkyLease Cargo	FedEx, UPS, DHL, ABX Air, Blue Dart, Toll

Source: Based on Merkert and Alexander (2018) market entrants have occurred, such as Aliscargo in Italy, ZFG Air in the UK, and Imex Pan Pacific Group (IPPG) in Vietnam.

Combination carriers have reacted to that operating environment and elevated air freight yields by chartering more dedicated freighter aircraft (which meant even more demand for ACMIs such as Atlas/Polar Air) and by using both the belly and above floor holds of their passenger aircraft for freight. The degree of converting of those passenger aircraft (i.e., A330-200 or B777-200ER) to a "preighter" configuration varied, as a full conversion requires costly processes such as removing seats, retrofitting doors, toilets, galleys, etc. As such, many airlines have chosen instead to largely keep the configuration of their passenger aircraft but carry the freight in seat packs that strap into the passenger seats. As the seat packs may damage seats and their packing/-unpacking being labor-intensive and associated with safety risks, it is unlikely that this practice will become a permanent future of the air cargo industry. Nevertheless, what this shows is that the different business models have different asset at their disposal which require different skill sets in terms of their finance, marketing, revenue, network, and capacity management.

Another strategic response of combination carriers to the pandemic has been to move away from widebody to narrowbody passenger aircraft which has further reduced the global belly-hold freight capacity. Also, their ambition to provide more fuel efficient and flexible point-to-point services rather than hub-and-spoke networks is detrimental to belly-hold freight. The emerging business model of ultra-long-haul direct passenger flights might be the most extreme case of that business model development (Bauer et al., 2020) but it amplifies the lack of belly-hold freight capacity as potentially a longer-term phenomenon.

As such, it is interesting to see how all-cargo operators and integrators keep growing their fleets. Due to the e-commerce boom, the latter have been complemented by online retailers building a chartered air cargo fleet presence themselves, most notably Amazon. Amazon Air, rebranded from Amazon Prime Air which transitioned into drone delivery services, is a virtual cargo subsidiary of Amazon Technologies operating a mixed fleet of Boeing 767 freighter aircraft, with freight services operated by Atlas Air, ATI—Air Transport International and ABX Air (all ACMIs, as shown in Table 1). A further blurring of business model boundaries appears to happen in a sense of airlines increasingly taking on roles of freight forwarders or ocean shipping companies now also operating air freight. For example, Denmark based Star Air is now operating specialized cargo lift capacity under the roof of the largest shipping line A.P.Moller-Maersk Group. These horizontal and vertical supply chain integration developments show that the traditional air cargo career path will not only be different in the future but is already potentially non-airline specific and diverse today.

4 Literature on the Future of Air Cargo

While not attempting to undertake an in-depth review of the extant literature, this section aims to briefly discuss observable trends in the literature that could inform future career choices in the air cargo logistics context. Our Scopus search of papers that use the keywords “air cargo” or “air freight” or “air logistics” has yielded 625 documents, which shows that air cargo is still a relatively under researched niche area. As with Tanrıverdi et al. (2020), we used various bibliometric packages in R to create the keyword network map shown in Fig. 5.

What can be observed in Fig. 5 is that air cargo research appears to be rather quantitative involving integer programming, stochastic analysis, simulation, optimization, and mathematical models (for a more in-depth review see Feng et al., 2015). The management of the causal relationship between aviation and economic development (Hakim & Merkert, 2016) is also of importance as is the value of air cargo to global supply chains (Shepherd et al., 2016), forecasting (Alexander & Merkert, 2017), contracting and decision making (Hellermann et al., 2013), and research on underlying drivers and future development of air cargo (Kupfer et al., 2017).

Clustering the literature further into 564 papers that were published until 2019 and 61 papers that were published in 2020 and 2021 enabled us to show that traditionally revenue management (Lin et al., 2017), has been a key skill as have been general logistics skills, as shown in Fig. 6.

Whilst risk assessment in air cargo and logistics is not a new theme (e.g., Shang et al., 2017), in 2020–21 it has become notably more prominent, as shown in Fig. 6. Judging by the literature, traditional risk management skills around pricing (Wen et al., 2020) as well as distribution channel and lane selection (Faghih-Roohi et al., 2020) are now enriched with skills more specifically related to disruption management (e.g., Feng et al., 2020) and schedule recovery, naturally often specifically

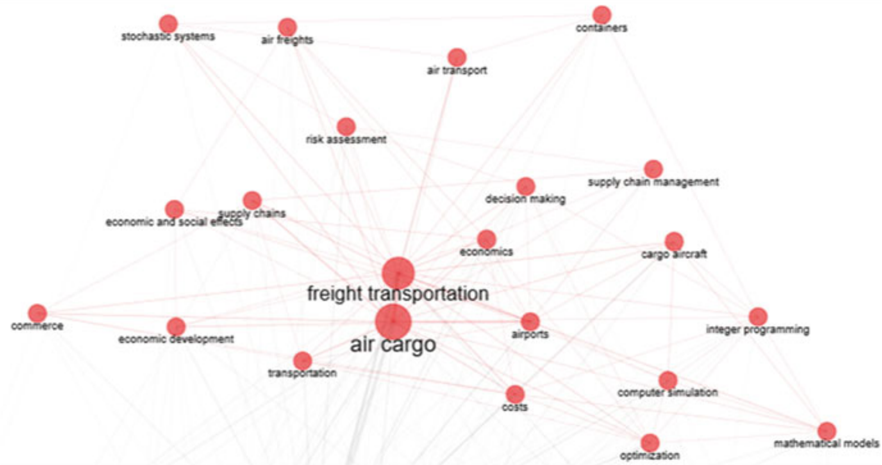

Fig. 5 Keyword Network Map of all Air cargo/freight papers (1960–2022)

Fig. 6 Keyword Wordcloud of Air cargo/freight papers from 1960 to 2019

Fig. 7 Keyword Wordcloud of Air cargo/freight papers from 2020 to 2021

related to COVID-19 (Shaban et al., 2021). Traditional areas such as logistics skills appear to be still of relevance, yet interestingly increasingly beyond just the air cargo airlines themselves and including airports as well as other elements of the air cargo supply chain (e.g., Hamdam, 2020) (Fig. 7).

5 Air Cargo Trends and What They Mean for Capabilities and Required Skill Sets

Interestingly, our literature review has further revealed that keywords such as digitization, security, drones, and sustainability (e.g., Bartle et al., 2021) are recently popular in the air cargo literature, which leads us to discuss in this section key industry trends and their potential impact on future skill requirements. There are standard skills such as leadership and technical skills that will continue to be important for successful air cargo managers, such as knowing the industry, the global aviation governance structure as well as analytical skills and customer-centric interpersonal skills, as air cargo is an industry that often still relies on transactions and B2B customer relationships being done via trusted and personal relationships. Information technology and data do assist air cargo managers in their decision making but picking up the phone and negotiating with supplier and customers is still as important as it always has been and most likely always will be.

Before we discuss trends around technology and sustainability, it is important to note that air cargo carriers have traditionally suffered from a lack of *supply chain visibility* compared to integrators and a *skewed risk/reward profile* as well as *lack of negotiation power* when fronting freight forwarders (due to sheer size differences and the latter being able to not only consolidate consignments but often being able to dominate markets and talking to both air and ocean shipping companies when negotiating shipments). As such, a career in an integrator or freight forwarder has and most likely still is, be the safer, and financially more rewarding bet compared to cargo airlines. Given that the recent boom in freight logistics and e-commerce has led to even further growth of freight forwarders, this negotiation power imbalance will remain a feature of the air cargo supply chain and it is possible to infer that negotiation skills and interpersonal skills will be crucial for a successful career in air cargo. Many large accounts are managed through interpersonal relationships and keeping them alive can break or make an air cargo airline. From our point of view, it would in fact be recommendable to having worked for a cargo airline and freight forwarder or even further up or down the supply chain, as specialist knowledge (e.g., revenue management) and quantitative skills (e.g., optimization, data analytics) can be learned (e.g., at university). Generalized knowledge and interpersonal skills is best to be experienced and obtained through doing and transacting with the other elements of the supply chain. As disruptions and volatilities on both the demand and supply side are going to increase in the future, it can be argued that not only resilience, empathy, and agility skills will be beneficial but that also loyalty and retention of B2B customers will matter even more than today (Tsai et al., 2021). As such, supported customer relationship management (potentially supported by data analytics and artificial intelligence but essentially still an interpersonal skillset) as part of marketing and procurement skills will therefore become an even more important asset.

As the *e-commerce* sector is growing fast, so are the volumes and margins of the integrator business model and with it the demand for *door-to-door services* and innovative last mile delivery solutions. Parcel lockers and drone delivery are no longer futuristic concepts but are happening today (Merkert & Bushell, 2020). As such future skills will be more diverse (e.g., planning and strategic management) than the traditional air cargo tool set and in fact will extend far beyond air cargo airline management. Similar to passenger airlines, where loyalty programs play a decisive role, it is likely that loyalty programs beyond B2B relationships will become more prominent and hence skills in that area (which have nothing to do with traditional air cargo management) sought after.

As discussed in the introduction section of this chapter, *digitization and automation* of air cargo are increasingly implemented. Despite many airlines still relying on legacy systems (sometime DOS systems that have been patched over the years) and many processes still being much more labor-intensive (and much less automated; e.g., ground handling) than those in other sectors, things are slowly changing. With the recent cash inflows into the sector, it can be anticipated that in this current golden decade of air cargo there will be further investments into technology and hence skills around data and digital literacy will be beneficial going forward. Good examples of what is going to be the new normal in any air cargo company are IATA's CagoIS (Business Analytics) and Digital Cargo (data sharing and supply chain visibility) and e-freight/e-AWB/Cargo XML (digital customs and transport documents such as the digital air waybill). Implementation of those has been slow pre-COVID but has been accelerated since then.

The elephant in the room for air cargo is however not COVID-19 but *environmental sustainability* concerns (e.g., Bartle et al., 2021). In Europe in particular but with other regions likely to follow, there has been public and political pressure to not only green aviation but also to replace short-haul and intraregional flights with high-speed rail. While this is currently focused on passenger services, the loss in belly-hold freight capacity as well as a likely refocus that will include cargo flights is something that air cargo manager need to account for in their strategies today. As such, a deep understanding of environmental and social sustainability implications of air cargo operations will become increasingly important. Not only the measurement and monitoring of the carbon footprint, noise and waste of air cargo but also the mitigation of residual exposure to environmental and supply chain disruption risks will be crucial for future air cargo managers. That said, the various business models and elements of the air cargo supply chain will experience this differently and in each of those slightly different skill may be required. For example, an understanding of the insurance business will become absolutely vital for air cargo airlines and freight forwarders but may be less relevant in the warehousing and distribution context and hence less of a key skill in integrator businesses. What will be required across all air cargo business models is forward thinking and the ability to ensure offering innovative and sustainable services.

Finally, we think that despite all innovation and disruption, a key skill for success in particular of combination carriers will be *strategic enterprise leadership*. As air cargo yields will normalize over the next year or two, it is likely that air cargo arms of combination carriers will lose their appeal for group CEOs of those carriers which could result in air cargo going back to being by-products. As such, air cargo managers should prepare for that future by upskilling in not just revenue and cost management but also intrafirm negotiation, communication/presentation and leadership skills.

6 Conclusions

The air cargo industry is due to lockdowns and travel restrictions stemming from COVID-19 and the accelerating e-commerce boom experiencing unprecedented demand and record profitability. As such, air cargo operators across all business models are suddenly confronted with the question of how to reinvest the welcome cash inflows. Fleet renewals that will help with growing sustainability concerns are an option for consideration as are growth and transformation programs that are going to assist the industry with adapting to disruption and technological change including digitization and automation along the supply chain, in particular in the last mile which already includes drone operations, an area that will see further growth.

All of this points to fantastic career opportunities for astute and agile graduates and young professionals, as the industry will require innovative spirit and customer-centric leadership skills. Given the international nature of air cargo and the horizontal integration currently happening, we believe that cultural and international experiences will be useful as will be traditional skills such as data analytics/literacy and an understanding of not just industry specifics and complexities; with the industry continuously expanding well beyond the traditional air cargo sphere and now including retailers and other stakeholders of the ever growing and diversifying air freight ecosystem.

The changing nature of the industry and growing concerns of its carbon footprint will require future leaders in this space to not only know how to measure but also how to monitor and manage emissions along the air cargo supply chain. Being able to collaboratively work with local but also international partners and academia in this regard will become even more important going forward.

Despite the accelerating digitization of the sector, the drone revolution and emerging air cargo business models, all requiring new skills, we believe that traditional communication, presentation, and negotiation skills will remain paramount for achieving long-term success in the air cargo industry. Once freight rates normalize, the complexities and power imbalances in the air cargo supply chain will, especially for managers of combination carriers, result in a return of the battles with not only the passenger divisions in their airline groups but also tough negotiations with the large freight forwarders. Being able to build trusted relationships with B2B customers and suppliers and leading air cargo divisions to commercial and environmental sustainability will continue to be key success attributes of managers in and along the air cargo value chain.

Management Perspective on Air Cargo Capabilities for the 2020: Enabling Connected, Efficient, Smart Solutions

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The air cargo industry is expected to have material change in the next decade. Developments will come from the need to address evolving customer demands, technology evolutions, government requirements, and shifting community expectation on areas like sustainability. In parallel, the capabilities required to support the air cargo industry need to evolve. Below is a summary of how some of the key changes will impact the skills required for the 2020s.

Technology and Robotics

One of the greatest areas of change for processing air cargo will be the expanded use of technology, including robotics, automated solutions, and the use of personal and wearable devices. Highly automated cargo facilities will reduce repetitive tasks and human error, while improving accuracy, speed, and safety (e.g., reduced manual handling or fall from height risk).

While technology will drive some operational efficiencies, operational roles will require more cross-skilling and capabilities to manage a broader range of responsibilities including quality assurance and end-to-end processing. Like all supply chain industries, demand will also exist for those with the technical capabilities to design, develop and optimize the technology and automation for cargo facilities.

Big Data

Access to large volumes of data will also evolve how air cargo is planned and managed. Programs like the IATA-led "One Record" initiative, to increase transparency across the supply chain, along with customer expectations for real-time information, will shift the type and data that is both consumed and shared. Data loggers, traceability trackers, booking and carriage forms, and similar tools will support in enabling connected solutions. Likewise, machine-learning and data-rich support tools, like revenue management systems, will be increasingly leveraged for improved predictability and decision making.

While air cargo operators may be able to leverage "off the shelf" solutions, created by data scientists, we can expect to see a higher demand for specialist data management and data analytics capabilities, to support the use and interpretation of data.

Stakeholder Expectations

Finally, stakeholder expectations will shape air cargo priorities for the future. Following a global pandemic, supply chain resilience will be front of mind and, with a heightened focus on bio-hazard risk, contactless solutions that are

(continued)

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digitally enabled will be preferred. Communities will also increasingly expect sustainable solutions and providers will need to focus on options such as sustainable aviation fuel, electronic vehicles, solar powered terminals, and carbon offsets. With digital and green solutions already front of mind for Generations Y and Z, we can expect an expansion of these capabilities to also be present in the Air Cargo Industry.

The decade of the 2020s will be a period of change and evolution. Beyond content-specific skills, strong behavioral capabilities will be increasingly critical to progress and evolve the air cargo industry. Individuals in the industry will need to be:

- *adaptable*, able to shift with technology developments and market changes;
- *emotionally intelligent,* to enable change;
- *collaborative,* to obtain diverse solutions to navigate broad stakeholder interests and address disruption; and,
- *boldly innovative,* willing to challenge historical models and ways of operating.

As an industry, we will need to commit to continued development of these skills and capabilities and continue to partner with educational facilities to ensure the future of the air cargo industry is well placed for the future.

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Maritime Logistics for the Next Decade: Challenges, Opportunities and Required Skills

Khaled Hussein and Dong-Wook Song

1 Introduction

In the late eighteenth century, the British experienced a number of improvements in the system of inland transport. Lower cost, greater speed, higher reliability and professionalism of transport services had widened markets. This development triggered a series of other improvements, such as accessibility to raw materials, increasing standardisation and the division of labour. Indeed, those improvements in transportation had stimulated region-based specialisation, scale of production and the emergence of new industries as a by-product. Simply, transport improvements fostered the Industrial Revolution (Ville, 1992) which, in turn, led us to the new era of technological innovations.

Globalisation, along with technological revolutions in transport sector such as containerisation and multimodalism, has reshaped the maritime industry. Consequently, the fundamental role of shipping and ports in global logistics and supply chains has been dramatically changed. Developments in maritime transport have triggered an increase in the demand for integrated and value-added logistics services. Having responded to changes in market demand, shipping companies and port operators start to develop their own strategies so as to offer high-quality logistics services via integrated transport and logistics systems in global supply chains.

A variety of physical, economic and organisational changes taking place in the maritime transport and logistics industry have evolutionarily triggered the introduction of maritime logistics concept in the early 2000s (Panayides, 2006). Maritime

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logistics is defined as 'the process of planning, implementing and managing the movement of goods and information which is involved in ocean carriage' (Song & Panayides, 2015, p. 55). Over the last two decades, maritime logistics has drawn much attention from both industry and academia alike. The current and future changes in economic, political and environmental spheres will continue to reshape the scenery of maritime logistics. The ongoing pandemic, along with disruptive events occurring around the globe, is adding up to challenges facing the industry and the global trade. Current and emerging technological and digitalisation innovations will certainly offer us opportunities that should be fully as well as wisely utilised for the benefits of human beings in general and of those working in the industrial sector. Being one of the core components of production and service functions, human capitals are expected to play a greater role in maritime logistics and related fields than ever before.

This chapter attempts to project the skills required in maritime logistics for the next decade by critically examining a few key global and industry-based challenges and, at the same time, identifying opportunities in an innovative and futuristic manner. Understanding the major dimensions that influence the current and future status of maritime logistics is deemed important, specially, in the light of the dynamic and disruptive global events. Furthermore, having a general view of essential and necessary skills for future jobs in the industry seems to be critical in achieving a sustainable and stable business entity.

Having the aforementioned points in mind, this chapter is structured as follows. The next section emphasises the role of the two major components of maritime logistics (viz., shipping and ports) in global logistics and supply chains. The third section provides an overview of global challenges and uncertainties in global logistics and supply chains. The fourth section offers a closer view on challenges embedded in the maritime logistics industry, followed by the fifth section having focused on some foreseeable and tangible opportunities. Finally, the last section of the chapter makes a concise discussion over the future jobs and skills required in the maritime logistics industry.

2 Maritime Logistics in Global Logistics and Supply Chains

The focusing point of maritime logistics is concerned with individual functions related to shipping (or sea transport) and also the effective logistics flows as a core entity of logistics integration system (Lee et al., 2012). Furthermore, the managerial function of maritime logistics encompasses sea transportation activities as well as additional logistics ones. Both the focusing and the managerial points differentiate *maritime logistics* from *maritime transportation*. This differentiation is due to the fact that, since maritime logistics is concerned with the whole logistics integration system and value-added logistics services, it becomes an integrated part of global logistics and supply chains (Panayides & Song, 2013). This section focuses on describing the two core components of maritime logistics—that is, shipping and ports.

2.1 Shipping as a Core Component of Maritime Logistics

The key function of shipping is moving cargoes between ports. Shipping is also engaged with other logistics functions and services which enhance the flow of cargo movements in complex maritime transport and logistics systems. These services include, but are not limited to, sea trade documentation, providing tracking information, intermodal services and other special handling services for customers who require particular services. The large share of cargoes carried by sea is bulk cargoes such as crude oil, iron ore and grain—a segment called ‘tramp shipping’; however, there is a growing demand for general or containerised cargoes in global supply chains—another segment named ‘liner shipping’. Liner shipping networks serve this growing demand in terms of frequency, direct accessibility and transits by increasing the number of trips from port of origin to port of destination, or by increasing vessel sizes, or both. Consequently, growing demand for containerised cargoes has been a driving force for an evolution in vessel sizes, liner services as well as the structure of liner shipping (Ducruet & Notteboom, 2012).

Since the 1970s, extant research has focused on economic efficiency with regard to increasing ship sizes and utilising economies of scale. These factors have helped liner shipping to reduce the freight rates and costs per TEU-mile in order to cope with highly competitive markets (Ge et al., 2019). The earliest containerships have been introduced in 1956; at the time the capacity of the ship ranged from 500 to 800 TEUs (Rodrigue, 2020). The evolution of containerised vessels has started in 1968, when the cargo-holding capacity of a container vessel became around 1530 TEUs and it was fully cellular. The largest containerships have evolved from a capacity of 5500 TEUs, which were referred to as the Post Panamax I and II containerships in 1995, to more than 23,000 TEUs which were referred to as the Very Large Containerships and Ultra Large Containerships in 2019. There are some larger containerships designed such as the Malacca Max which could carry up to 30,000 TEUs; however, it is predicated that these ships will not be constructed unless there are sufficient demands for volumes on specific routes and ports (Rodrigue, 2020). Furthermore, a number of issues hinder further development of container vessels to increase the size; these include tighter environmental regulations on energy efficiency and emission control and turbulent market conditions of container shipping (Ge et al., 2019).

Global trade is highly dependent upon liner services that could be achieved by vessels being operated as a common carrier on the pre-announced and regular schedule of time and route. The concept of economies of scale and the demand for integrated logistics services encourage shipping lines to adopt various economic or organisational integrative strategies with other shipping lines and/or with ports—that is, horizontal and vertical integration. The rationale for moving towards the integration is regarded as a response to increasing demand from the shippers and as an operational strategy to enhance their control over global logistics and supply chains.

2.2 Port as a Core Component of Maritime Logistics

On the other hand, ports have unique and complex structures of social and technical systems responsible for transferring cargoes and passengers between land and ships or vice versa (Rodrigue, 2020). The evolution of ports is accompanied with the evolution of shipping and global trade. Similar to the case of shipping, globalisation, containerisation and multimodalism have triggered numerous developments in the port industry. These developmental stages are referred to as 'generations'. Based on the United Nations Conference on Trade and Development, there are four main port generations. Recent research, however, introduced the fifth-generation ports which are referred to as 'customer-centric ports' (Flynn et al., 2011) and its updated version by Lee and Lam (2016).

The most significant era of port development was in the early 1990s. The development of global logistics, supply chains and transport markets has led to a series of changes taking place in the role of ports as a gateway between sea and land. Ports have been traditionally considered among the most important logistics links in various stages of global supply chain systems such as production, distribution and consumption. This role has triggered the integration of ports into global supply chains and shed light on the role of ports from a logistics channel perspective, a trade channel perspective and a supply channel perspective (Bichou & Gray, 2005). Integration of ports into supply chains emphasised the role of ports as networking sites where players of a supply chain are brought together (Panayides, 2006).

The integration of ports into supply chains has been also driven by the liner shipping industry that was concerned with providing their customers with both door-to-door and value-added logistics services. This pattern of services has put an additional pressure on a number of members working in the field of maritime logistics where competition among shipping lines was increased, thus leading to competition among ports and container terminals. This change has been extended further to the way for ports to measure their effectiveness and other essential performance indicators as an effort to enhance their competitiveness. These changes have certainly affected a port's goals and its strategies in order to sustain their business and have an impact on all maritime logistics stakeholders in one way or another.

The changes that have taken place in the shipping and port industry during the last two decades are out of the scope of this chapter; however, the chapter focuses on the current external and internal changes to maritime logistics industry. More specifically, changes that put pressure and provide opportunities to main components of maritime logistics industry will be discussed. Accordingly, the following section focuses on a number of pressing questions related to *external challenges* that face the maritime logistics, global logistics and supply chains and *internal challenges* that are associated with maritime logistics per se.

3 Challenges in Global Logistics and Supply Chains

Global logistics and supply chains are facing numerous challenges and uncertainties that form multiple issues for the majority of stakeholders in the present time and probably in the future. These challenges could be categorised into economic, political, environmental and social forms. Below discusses a few major challenges and uncertainties that (in)directly influence the maritime logistics industry from various aspects. It is not claimed that the following issues are the only ones; rather, they are the most obvious or exemplary challenges that create a concern to the maritime logistics industry and its underlying businesses including labour forces and their employability.

3.1 Global Economic and Political Unrest

It is well noted that economic and political disturbances have a negative influence on multiple key stakeholders of maritime logistics. In a general term, economic and political unrest cause multiple disorders to international trade, while these disorders directly affect the balance of demand for and supply of goods and services in a globalised environment. At the time of the Great Depression, the shrinkage of world trade was still considered the strongest shock to international trade in the modern history (Madsen, 2001). Similarly, the 2009 financial crisis led us to experience serious distortions on political and social aspects. The crisis led to sharp inclining of political polarisation and the rise of the left and right movements in Europe and the USA (Mukunda, 2018). One of the repercussions the financial crisis caused was supressing the growth of the container shipping market. The growth of the maritime industry has stopped for the first time in the history with a steady decline in the rate of containers shipped around the globe (Bomboma & Mutinga, 2016); this has led to serious damage to port industry as well.

The ongoing trade war between the USA and China started in March 2018 when the USA imposed additional tariffs of 10–25% on the majority of goods imported from China (Cho et al., 2020). The trade war between the two countries in the global value chain has led to a decrease of global GDP by 0.4% (Gong et al., 2020) and volatility of share prices worldwide due to increase of tariffs which led to decline in global investments and manufacturing purchasing indices (Macola, 2020). In other words, the conflict between the USA and China could further shrink international trade and logistics demand; this will then lead to distortion to global supply chains (Cho et al., 2020). Saka (2019) identified four main influences of the trade war between the USA and China on shipping and logistics. These influences involve diversified import sources, increased consolidation in the logistics industry, increased focus on foreign trade zones and growth in domestic transportation.

A decline in the world economy also indicates that production is shrinking; this means that the demand for raw materials is declining. Consequently, the demand for international trade and transportation of essential raw materials such as iron ore, coal and crude oil will decrease. These series of chained events lead to a significant and negative complication on the shipping freight market (Gong et al., 2020). With regard to the port side of maritime logistics, the decreased traded volumes heavily influence the port cargo. Cho et al. (2020) highlight that port cargoes are expected to decrease by trillions of tons, then leading to a catastrophe which could occur in global maritime logistics as a consequence of strong decline in global trade orders.

An example of the political and economic ongoing changes in the global geopolitical scene is the Chinese Belt and Road Initiative or the Silk Road. The Silk Road is a strategic initiative and vision which connects Chinese mainland to Europe by land via the 'Silk Road Economic Belt' and by ocean via the 'Maritime Silk Road' (Yang et al., 2018). This initiative will probably lead to increasing China's role in global capitalist economy along with dramatic changes in global political and economic scene. Whether the objective of the initiative is to enhance China's power and influence or to provide stability and development for Europe and Asia, the initiative itself will be under a new political and economic order across both continents (Summers, 2016). It is indubitable that the geopolitical implications of the Silk Road will be associated with global implications on maritime logistics industry. Two railway systems are expected to impact the current shipping service from China to Europe. The first is the New Eurasia Land Bridge which will connect China and other Eurasian countries, and the second is built to connect Southern European hub ports to their hinterland (Yang et al., 2018). These developments will consequently have an impact on ports as well. For instance, COSCO, a Chinese liner shipping company, has signed an agreement for concession and investment in the Greek Piraeus port. It is expected that the Piraeus port will be transformed to one of the biggest transit hub ports in Europe after COSCO takes over 67% of its shares (Yang et al., 2018). It seems to be an obvious fact that the Silk Road initiative is expected to be under enormous changes and challenges for global logistics and supply chains in terms of connectivity and sustainability (Thürer et al., 2020).

3.2 Climate Change and Sustainability

The global political and economic unrest is not the only challenge that faces global logistics and supply chains. The world is also facing a serious and rapid change of climate. The influence of a disruptive and uncontrollable levels of climate change might lead to catastrophic events such as starvation, destruction, migration, disease and war (Monios & Wilmsmeier, 2020). Furthermore, global warming has become an important issue mounted by the increase of CO_2 emissions, leading to rise of sea levels and threatening coastal zones. Maritime shipping is considered as perilous source of both greenhouse gasses and other pollutants (Liu et al., 2021), which contributes directly to global warming issue. Congestion of ships at ports' waiting areas and at berth is considered a substantial issue. This is because ships consume electric power generated by diesel engines, leading to increase of CO_2 emissions at sea and land. Accordingly, with the increasing international trade, maritime logistics is becoming unneglectable source of pollutants.

A number of challenges are facing sustainable development of shipping. Wu et al. (2020) introduced four challenges or barriers which face shipping sustainability. These challenges involve the cross regionality of sustainability issue, the transdisciplinary of global logistics, lack of unified understanding of sustainability concept and lack of governmental support. In the same line, ports face a number of challenges and issues which should be considered for future sustainable development. These issues are related to port infrastructure, cooperation among ports, connectivity between port and cities and social integration of ports (Nebot et al., 2017). Accordingly, both climate change and maritime logistics sustainability are interrelated issues that are considered as serious global challenges that face global logistics and supply chains.

3.3 Current and Future Cataclysmic Events

Global cataclysmic events have an instantaneous impact on global demand and supply patterns. Consequently, they influence global trade, causing a disturbance to global supply chains and logistics. Cataclysmic events can involve natural events such as the Japan tsunami in 2011 or economic events such as the 2008/2009 financial crisis or health events such as the spread of 'coronavirus disease 2019' which is also known as COVID-19. The pandemic is considered as the second major economic crisis of the first part of the twenty-first century leading to new and unprecedented repercussions on global supply chains and maritime logistics (Notteboom et al., 2021).

The current COVID-19 pandemic is a part of disruptions that occur to supply chains which can take multiple ways. Specifically, disruptive events that occur to supply chains can mainly take place in three ways (Notteboom et al., 2021)—demand shock, supply shock and lack of distribution capabilities. Global health crises such as COVID-19 contributed to disruptions of all three. On the supply shock, the pandemic created a sudden change in the availability of some essential raw materials and manufacturing capabilities. It directly influenced the labour necessary for procurement of these materials along with its transportation and logistics. On the demand shock, the global disease contributed to unexpected change in demand of several items such as food and specific product groups such as computers used for distance work and education. In the same line, demand of customers on energy was declined parallel to declivity of mobility and prevalence of global lockdown. The global pandemic also contributed to disturbance of distribution facilities such as lack of workforce and closure of ports, airports and distribution centres. This means that even if there are no issues in demand and supply flows, the outbound and inbound logistics will be influenced by lack of distribution facilities.

It is highlighted that 75% of newly emerging diseases are zoonotic which means that they are originating from animals (BBC, 2021a, b). It emphasised that, in the future, there are three main viruses that might pose a threat to the globe. These viruses are MERS in camels in Africa, Nipah in bats in Asia and swine flu in pigs in the Americas and Europe. Accordingly, more safety and security regulations should be developed by international trade organisations and maritime logistics stakeholders in order to obstruct the next pandemic. Accordingly, global supply chains and logistics should utilise the surge of technological advancement to secure a smooth flow of materials in times of global catastrophic and cataclysmic events.

4 Challenges and Opportunities in Maritime Logistics

In the previous section, the global challenges and uncertainties in the global logistics and supply chains were discussed. This section focuses on the challenges facing maritime logistics industry, specifically, shipping and ports. Challenges facing shipping and ports are numerous; however, the major challenges are related to disruptions that lead to imbalance of demand and supply which directly impacts maritime logistics industry. The current major disruptive events are related to pandemics, while the future challenges are mainly related to safety and security issues along with disruptions caused by labour versus technological aspects. Accordingly, this section focuses on these aspects which cause a major disturbance to maritime logistics industry.

4.1 Disruptions

Disruptions in maritime logistics are caused by various aspects and can have numerous categories. For the purpose of this section, only major external disruptions and its fundamental repercussions on maritime logistics will be discussed. Disruptions in maritime logistics are part of disruptions that occur to global supply chains. Wagner and Bode (p. 309) defined supply chain disruptions as the combination of (i) an unintended, anomalous triggering event that materialises somewhere in the supply chain or its environment and (ii) a consequential situation which significantly threatens normal business operations of the firms in the supply chain. Based on this definition, disruptions which occur to maritime logistics can be related to either catastrophic risks such as pandemics and terrorist attacks or infrastructure risks such as man-made accidents (Zhu et al., 2017). This section provides a brief discussion over four main subcategories of disruptions. Typically, the section considers COVID-19 pandemic, accidents, terrorism and hijacking and finally cyberthreats.

Two main repercussions occurred in the shipping industry as a result of the spread of COVID-19. First, in February 2020, the first wave of blank sailing occurred as a result of the supply shock in China. 36% of scheduled sailing was withdrawn on the Asia-Europe route and 28% of transpacific haul capacity (Notteboom et al., 2021). More than 11% of the world container fleet was withdrawn in April–May 2020. Blank sailing had a serious impact on port call sizes and the number of containers handled per call, leading to an operational disturbance to ports. Second, shipping lines innovated new services and storage solutions in order to minimise the shortage in demand and booking cancellations. To allow customers to adjust delivery dates, shipping lines decided to introduce new clauses related to suspension, detention and storage of containers (Notteboom et al., 2021). These clauses helped customers to adopt the delivery dates to their own requirements while controlling storage costs, providing customers with flexibility and significant cost savings (Notteboom et al., 2021). Furthermore, the pandemic emphasised the importance of strengthening intraregional shipping networks and might lead to an impact on market structure, especially, mergers, acquisition and alliance among small shipping lines.

Following the shock which happened to the international trade, ports have had to adopt a number of measures in order to minimise negative repercussions of COVID-19. Since the demand was low, terminals started to establish a high utilisation levels of terminal yards and to rebalance large volumes of empty container flows because they had to be repositioned back to their origin. The main challenge, however, was the decreased number of port calls. The outbreak of COVID-19 led to decreased vessel calls to China by 15.5% compared to similar week in 2019 and a global decline by 3.6% compared to the same period in 2019 (Notteboom et al., 2021). At present times, although there are some positive indicators that ports are recovering, ports and shipping lines should strategically plan for similar events that might occur in the future. Ports and shipping lines should also utilise technologies such as digitalisation in order to facilitate quick responses to pandemic crises such as this. Notteboom et al. (2021) emphasised the role of automation of port services and digitalisation of port community. Technologies were effective and supportive instrument against personnel shortages and conditions imposed by COVID-19.

Major port and shipping accidents are significant challenges for maritime logistics. Major accidents such as the Tianjin Port fire explosion in 2015 and the Beirut Port explosion in 2020 lead to a wide range of damages. For instance, the Tianjin Port fire caused $9 billion losses (Wang, 2016), while the Beirut Port explosion caused $15 billion losses (Hussain & Cohn, 2020) among other financial and social damages. In general terms, accidents that occurred during transport and cargo handling inside ports have enormously increased during the last years; however, 27% of accidents in European ports are caused by human factors (Lecue & Darbra, 2019). These accidents led to massive damage to port infrastructure and superstructure impacting the economic and social aspects in port city. Similarly, shipping accidents have been considered as one of the major contributors to economic and social impacts. The complex nature of shipping accidents is considered as the major burden to analyse main combination of factors leading to a specific accident event (Coraddu et al., 2020). It became evident, however, that 66% of shipping accidents are caused by human factor (Coraddu et al., 2020). Accordingly, numerous automation technologies are introduced worldwide in order to reduce the likelihood of maritime accidents (Mallam et al., 2020).

Maritime accidents have a calamitous repercussion on global trade if they take place in a vital geographical location. The Suez Canal blockage could be a good example for a worldwide shipping crisis as we experienced in late March 2021. An ultralarge container ship blocked the Suez Canal during its journey from Yantian, China, to Rotterdam, Netherlands. The accidental grounding of the 400-meter-long ship on one of the canal banks prevented other vessels from passing until the Suez Canal Authority successfully freed the ship on March 29, 2021 (BBC, 2021a, b). The main cause of deviation of the ship is not clear; however, the Suez Canal Authority stated that there was a complex of elements that led to the accidents. These causes might be by strong dusty winds, technical problems and/or human errors (DW 2021a, b).

The blockage of the Suez Canal, one of the most important and busiest global trade routes, led to obstruction of around 50 ships per day, holding up an estimated $400 million per hour in trade (Baker et al., 2021). The costs of the blockage are still unspecified; however, the estimated costs for global trade can range between $6 and $10 billion dollars (Nasr, 2021). The blockage led to increase in oil prices (DNA, 2021) among other disturbances to global supply chains that will continue for months (Ames, 2021). The Suez Canal blockage emphasises the extent to which the world became connected, integrated and globalised, while incidents in maritime logistics can have catastrophic influences where the domino effect takes place (Ames, 2021).

Terrorism and hijacking at sea can be reflected by the incidents of maritime piracy considered as the oldest international crime (Otto, 2020). Though piracy became obsolete by 1839, it started to receive public attention when pirates started to hijack ships and its crew in the late 2000s, off the coast of Somalia. Piracy is currently a major concern in other regions of the world such as Southeast Asia and West Africa (Otto, 2020). The core challenge of piracy is not only limited to hijacking but also other illegal activities such as exploitation of illegal drugs, weapons trade and human trafficking (Donna, 2020). In the same vein, port terrorism has been receiving attention since the 9/11 attacks on New York and Washington in the USA. Over the last two decades, a number of strategies have been established in order to face terrorist attacks on ports. For instance, the International Maritime Organization has established the ISPS Code in 2001, the USA has established the Maritime Transportation Security Act in 2004, and the European Union has established a voluntary security initiative known as the European Union Authorised Economic Operator. Presently and over the next decade, the attention to terroristic attacks on ports will fade in favour of cyberattacks and smuggling (Otto, 2020).

Cybersecurity is one of the pressing challenges that face the current and future maritime logistics industry (de la Peña Zarzuelo, 2021). Cyberthreats or cyber-risks can involve any risk in cyberspace (Cheung & Bell, 2021), embedded in any digital or virtual connection in an electronic medium. Accordingly, the increasing adoption of advanced technologies is accompanied with increasing cyber-risks, creating opportunities for hackers. Thus, the main goal of cybersecurity is to build a secure cyberspace. In general terms, any industry using technological and digital tools is vulnerable to cyber-risks, specifically maritime logistics industry. While ports and shipping lines and other maritime logistics stakeholders depend enormously on interconnectivity and integration among each other in order to enhance operational efficiency, they face an increase of cyberthreats and cyberattacks (Tam & Jones, 2019). Examples for these attacks can involve the incident of A.P. Moller—Maersk in 2017 which led the Danish shipping giant to lose millions of dollars in its logistics business (Cheung & Bell, 2021). Similarly, ports can also face a number of disruptive repercussions as a result of cyberattacks. For example, on May 9, 2020, computers that coordinate the flow of shipping and inland transport have all crashed at once at Shahid Rajaee port in Iran. The incident led to massive congestion and backups on seaside and landside (Warrick & Nakashima, 2020). Another incident took place in Port of Antwerp where small devices were attached to DP World's office computers by a group of organised criminals (Otto, 2020).

4.2 Labour Forces

The changing and unstable dynamics in maritime logistics industry is leading to significant transformation in labour market of ports and shipping. Specifically, in the last two decades, there were two main changes that affected maritime logistics labour markets: that is, (i) changes in port organisational structure such as privatisation and (ii) ambition of shipping lines to gain greater control over logistics chains (Bottalico, 2019). Moreover, the aspiration of main players in maritime logistics to establish economies of scale strategies has led to mergers, acquisition and alliances among shipping lines and ports. The horizontal integration among shipping lines and the vertical integration between shipping lines and ports have increased the demand for even more large vessels. This development has significantly contributed to a reduction of port calls and less demand for employment. Moreover, most recently, the health emergency resulting from COVID-19 pandemic and advances of technology and digitalisation have increased the complexity of the ongoing dynamics of maritime labour markets (Klumpp & Ruiner, 2021).

The ongoing COVID-19 crisis is speeding up the digitalisation and automation transition in maritime logistics as well as other numerous industries. This will lead to structural changes in working conditions, job profiles, training systems and the required skills in the maritime logistics heterogeneous workforce (Klumpp & Ruiner, 2021). In general terms, logistics and transportation industry become a knowledge-intensive service industry which depends on usage and analysis of data. Similarly, technological innovation such as automation and robotics is currently getting an unprecedented attention in maritime logistics industry (Parola et al., 2020). Both digitalisation and automation, along with other information and communication technologies, are representing a sensitive issue to maritime logistics chain. For instance, since the 1960s, European ports have experienced a shrinkage of workforce (Klumpp & Ruiner, 2021). This fact is continuously increasing and threatening the social sustainability of maritime logistics industry.

The impact of automation and innovative technologies on employment in maritime logistics is uncertain (Klumpp & Ruiner, 2021); even for countries in the same geographical regions or with similar economic attributes, the risk of automation on employment varies substantially. It is projected, however, that automation will lead to elimination or redundancy of jobs that require low-skilled labour. For example, it is projected that by 2040, 90% of crane operations and docking will be automated (World Maritime University, 2019), and in port sector the jobs will be reduced by more than 8% worldwide. This means that the required skills of maritime logistics labour are changing along with the job profiles, working conditions and training systems. Accordingly, the major challenge for maritime logistics is to cope with these changes by providing education, training and reskilling opportunities for its workforce in order to engage in futuristic technological and digitalisation evolution.

Crew retention is considered specific challenge which is currently facing shipping industry and will probably cause a serious downside in the future. The shortage of seafarers is one of the main challenges facing the shipping industry (Kilpi et al., 2021). There are multiple drivers for seafarers who shift to landside jobs. Some drivers are related to social aspect where separation from home and family negatively impacts their psychological conditions. Other drivers are related to inadequate emphasis on employment branding, insufficient employer support and lack of governmental initiatives that target seafarers and related job profiles and groups (Thai et al., 2013). Figure 1 summarises the overlapping relationships and effects among global challenges and maritime logistics challenges.

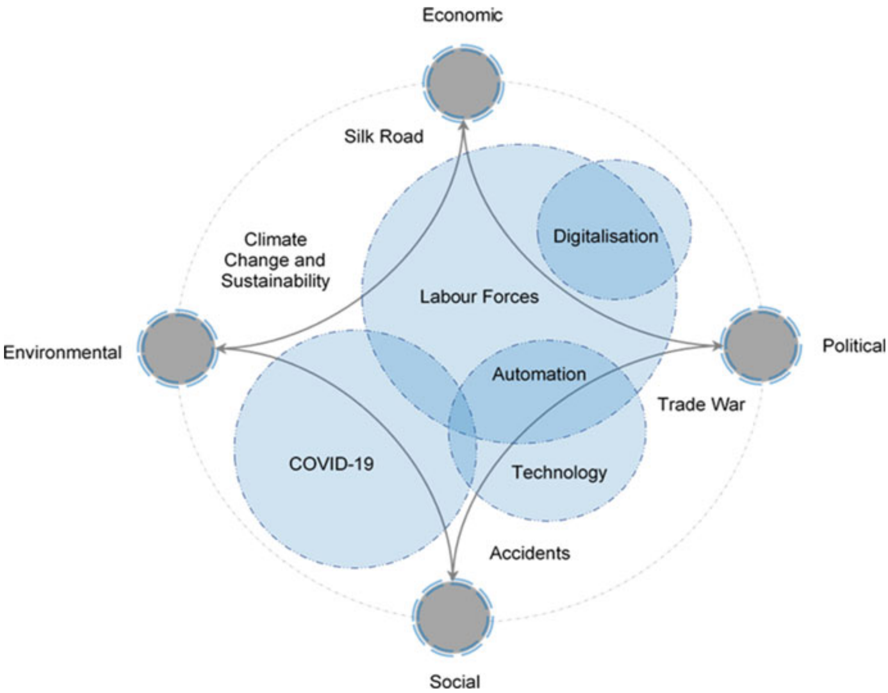

Fig. 1 Major challenges in maritime logistics

4.3 Opportunities

On the other hand, maritime logistics industry has also identified a number of opportunities that should be utilised in order to face these challenges. In fact, the majority of opportunities in maritime and logistics industry are concerned with the current and futuristic information technologies and digitalisation advancements and innovations. Accordingly, this section focuses on the major technological opportunities in maritime logistics industry. Understanding the importance of these aspects is fundamental for current and future maritime logistics practitioners and stakeholders in order to enhance their planning and decision-making about facing challenges of maritime logistics industry.

Technology and digital innovations have a substantial importance for all aspects of maritime logistics industry. The current and future evolution of technology and digital innovations are also shaping the whole maritime supply chains architecture (Carlan et al., 2017). Maritime logistics have always been depending upon and concerned with information and communication technology used by shipping lines and ports. Digital technologies are important because it improves productivity (Heilig et al., 2017), quality of strategic planning along with decision-making (Meng et al., 2020) and labour working conditions and their productivity (Sima et al., 2020), among others. At the present time and in the future, however, many technological aspects and digitalisation tools and applications are being investigated. The increasing attention to port automation and autonomous ships implies that more technologies and digital innovations will be introduced in the future.

There are more than 40 maturing novel technologies that have been adopted or will be adopted in transport industry (World Maritime University, 2019). Based on systematic literature review, Parola et al. (2020) highlighted 13 promising digital technologies for maritime supply chains such as 3D printing and augmented reality; however, only 4 technologies have proven their applicability to maritime logistics industry. These technologies are big data analytics, Internet of Things, location detection and cloud computing. Other technologies may fit to maritime logistics industry in the future; however, until now, there is limited evidence on their full applicability and operationalisability.

Big data analytics is considered essential for multiple logistics activities such as inventory planning, warehousing management and distribution (Vásquez Rojas et al., 2018). In shipping, the big data technologies are considered as essential tool for shipping operations for present times and the next decade (Yang et al., 2019). Using big data concept along with artificial intelligence, shipping firms can monitor vessel's performance in order to enhance its operational efficiency (Munim et al., 2020). Big data also is becoming more essential for safety and security of ships (Zhang et al., 2014) and can be utilised for improving communication among maritime logistics stakeholders in order to enhance quality of information, improve effectiveness and reduce transaction costs (Sarabia-Jacome et al., 2020). In ports, big data integration can be used to manage the enormous data shared among port authorities, container terminals and shipping companies in order to improve decision-making (Sarabia-Jacome et al., 2020) and evaluate port competitiveness (Peng et al., 2018) and port connectivity (Jia et al., 2017).

The Internet of Things is simply an information and communication technology based on the internet (Ding et al., 2020). It applies numerous information sensing technologies and combines network communication technologies in order to communicate, exchange and control array of data among physical and virtual objects (Ding et al., 2020). Internet of Things can have many applications in maritime logistics. It can be utilised in quality-oriented tracking, tracing and monitoring. Furthermore, it can be useful for providing unique identifiers and electronic container seals (Ding et al., 2020). The use of Internet of Things can also extend to other sub-streams in maritime logistics such as warehousing and storage of cargoes in port terminals and hinterland logistics centres (Parola et al., 2020), as well as improving integrated logistics services for port users. Accordingly, the Internet of Things can improve port operational efficiency, service differentiation, decision-making as well as strategic management within maritime supply chain.

Location detection and cloud computing are found to be essential for securing smooth flow of cargo in the maritime logistics chain. Shipping lines use location detection in order to share the specific location of the shipment with its customers; similarly, ports use the technology in order to advise customers with the readiness of their shipments to be collected. On the other hand, cloud computing simply allows authorised users to utilise real-time services by multiple applications using their own devices, such as mobile phones or laptops. Cloud computing helps maritime logistics stakeholders to take real-time decisions in order to organise, control and coordinate their logistics services. As mentioned earlier, the complexity of maritime logistics operations results in huge sets of data that can be processed using artificial intelligence and data mining; indeed, these technologies will support the next decade of automation and robotics in maritime logistics industry. Figure 2 illustrates the major four technological advancements in maritime logistics and their potential impact on the industry.

As mentioned earlier, automation and robotics technologies are receiving increasing attention from multiple stakeholders in maritime logistics industry (Parola et al., 2020). Although their potential negative impact on employment patterns in the future, these technologies are inevitable and will reshape the future of logistics, specifically maritime logistics. In shipping, unmanned autonomous ships are considered as cornerstone for a competitive and sustainable maritime industry, because of its contribution to economies of scale and maritime transport decarbonisation (Gong & Cullinane, 2018). Autonomous ships are expected to be operated in special trade areas and specific restricted regions, while control and support will be provided by experts at centralised operation centres at shore (World Maritime University, 2019). Furthermore, some inspection operations will be accomplished by underwater or airborne inspection drones. On the other hand, a number of ports around the globe are currently considering full automation of their operations. Specifically, in China, many container terminals are moving towards automation such as Shanghai, Qingdao and Tianjin, among others (Hu et al., 2016). Automated container terminals involve automated ship cranes which enhance container throughput rates. Furthermore, automated terminals involve automated stacking cranes and automated guided vehicles which can be beneficial for improved optimisation of yard.

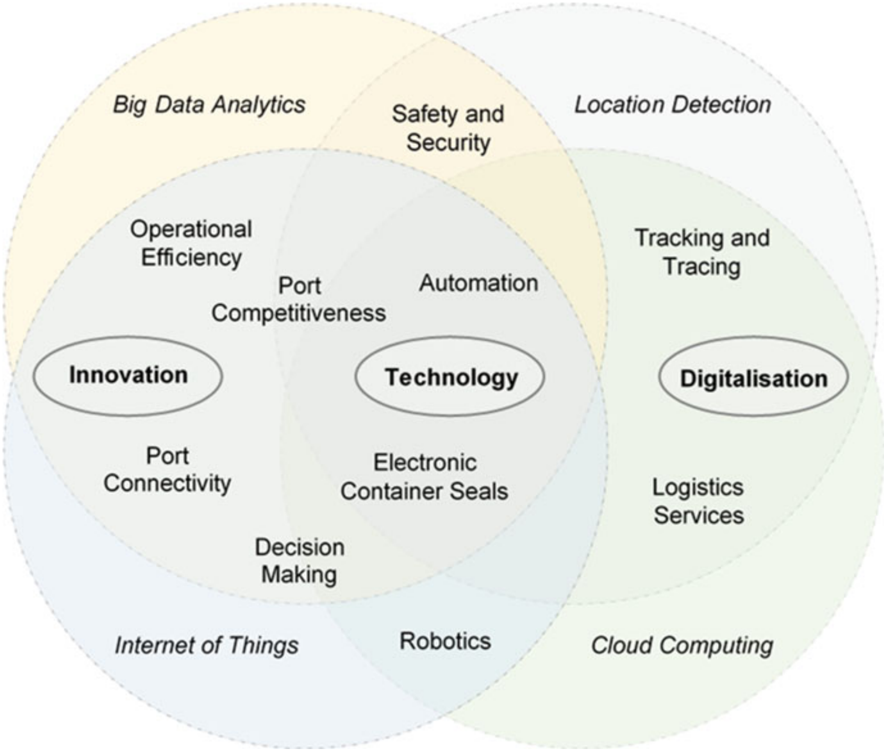

Fig. 2 Technologies and impacts on maritime logistics

Although there are numerous benefits of technology and digitalisation for maritime logistics industry, there are a number of factors that can decelerate or delay the adoption of technologies. World Maritime University (2019) emphasised that these factors can involve the readiness or feasibility of the technology for large-scale application, the economic benefits of the technology, the availability and capability of labour to handle the technology, the readiness of governmental authorities to adopt the technology, the capability of users to master the technology and the social acceptance of the technology. The report highlights that highly automated ships can be mostly delayed by governmental regulations and governance, and questioned economic benefits and costs.

5 Skills for the Future

Technology, digitalisation and innovative ideas put individually and collectively forwards a number of common challenges to the maritime logistics industry. These challenges could be related with a number of factors such as economic and social factors. The context of this section is concerned with the social factor, in contrast to

Sect. 4.2 that discussed the social factor as a challenge for technological adoption. This section discusses the major futuristic jobs in maritime logistics industry based on the current trends and prospective opportunities regarding potential technological and digitalised advancements. It also highlights skills required in order to cope with the future of maritime logistics industry in the next decade.

5.1 Future Jobs in Maritime Logistics

Technology and digitalisation are reshaping supply chain and logistics industry, specifically maritime logistics. Maritime transport industry only is associated to 3.3 million jobs and contains the highest employment in service industries (World Maritime University, 2019). In the wider scope, the World Economic Forum (2020) identified the emerging and redundant job roles in transportation and storage among other business fields. The report emphasised a number of emerging job roles which are related to technology and digitalisation. These job roles involve artificial intelligence and machine learning specialists, digital marketing and strategy specialists, data analysts and scientists and software and applications developers. Furthermore, the report highlighted that supply chain and logistics specialists and ship and boat captains are among the top ten emerging jobs. Moreover, supply chain and logistics specialists are in high demand in China and Thailand. These jobs are expected to flourish in the future, specifically the next decade, along with the technological and digitalisation evolution in supply chain and logistics fields.

Bottalico (2021) expressed that the future jobs in ports will depend on ‘less muscles, more brain’ (p. 121), highlighting that more technicians specialised in automated port systems will rise. Referring to the case of Port of Antwerp, the author has underlined that many middle-paid paperwork job profiles will fade, and management jobs will be more complex. Job profiles with repetitive and routine tasks will probably be accomplished by programmed machines. This is to say that job profiles such as crane operators and dockers have high potential or probability for automation, while ship engineers and dock supervisors have the least automation potential (World Maritime University, 2019). Consequently, most tasks related to job profiles with mostly low- and middle-skills requirements will become obsolete by 2040. Accordingly, it is more beneficial for service firms in maritime logistics industry to shift their focus towards learning that will benefit the individual and the organisation rather than providing training only. This development process will encourage employees to refresh their knowledge and to become skilled in innovative technologies and to improve their capabilities following changes in the global logistics business environment (Pantouvakis & Bouranta, 2017).

5.2 Future Skills in Maritime Logistics

With regard to the current and future challenges and technological advancements which are merging into maritime logistics industry, competencies and skills required in the industry as a result of these challenges are evolving. Research work that discussed this vital issue, however, is still limited. The core importance of skills is that they are essential for the development of dynamic capability of firm in order to sustain its competitiveness in turbulent business environments such as supply chain and logistics (Tatham et al., 2017). Accordingly, well-trained and skilled logistics professionals are in high demand (Van Thai & Yeo, 2015).

Employees in supply chain and logistics need to have cross-functional understanding of diverse business fields. They also need to have a wide range of skills such as strategic decision-making, communication, leadership, intercultural, analytical and information technology skills (McKinnon et al., 2017). Specifically, in maritime logistics, employees need to learn new skills and be alert to any external changes, and they should have the authority to make decisions and to be empowered (Lee & Song, 2010). Eventually, employees in maritime logistics need to be more competent because this criterion will be acute in the future (Kilpi et al., 2021). Since the future of maritime logistics has a wide array of challenges and the vast majority of opportunities are related to technology and digitalisation, the rest of the discussion in this section will focus on the problem-solving skills. Specifically, this set of skills is depending upon sets of information technology skills in supply chain and logistics (Rahman & Qing, 2014).

The results highlighted by Poist et al. (2001) indicated that it has been very important for logistics managers to have information systems and computer skills. In the same regard, the authors highlighted that technological literacy and quantitative skills perceived a greater increase in importance. Wu (2006) found that system analysis and quantitative analysis, mathematics and statistics scored the highest regarding importance to managerial skills. Based on a survey which involves 123 members of the Council of Logistics Management in the UK, quantitative and technological skills are considered one of the fundamental categories of supply chain management competencies (Wong et al., 2014). The authors found that potential employees in transport should have experience in transport management software. Rahman and Qing (2014) highlight seven skills related to information technology in supply chain. These skills involve quantitative modelling skill, software knowledge, spreadsheet abilities, statistical skill, information technology skill and skills related to internal integration and external integration of information flow and systems.

Dubey and Gunasekaran (2015) highlight that sustainable supply chain skills will arise in the future. The authors emphasise that the use of the latest technology is at the core of required skills among other various skills. Jordan and Bak (2016) highlighted that quantitative skills are among the main skill groups that should be acquired by supply chain graduates. Specifically, the authors highlighted the importance of finance and numeracy skills, information technologies skills and analytical and statistical skills. Furthermore, the author also emphasised the importance of management of complexities and change, along with negotiation skills. Kotzab et al. (2018) analysed 832 job postings in the field of logistics and supply chain management and identified 280 skills and competences related to job profiles of logistics and supply chain managers. The authors emphasised the importance of mathematical and technological competencies as well as digital competencies among eight key competencies for lifelong learning in a holistic competence model. In the same line, Mageto and Luke (2020) provided a comprehensive skills framework that focuses on supply chain. The authors highlighted that the increase of e-commerce and sustainability awareness, as well as emergence of blockchain technologies, triggers the need for supply chain managers who are equipped with technical skills that help them in designing futuristic supply chains.

As mentioned earlier, only a few research works have discussed the required skills in maritime logistics industry in the future. Only recently, Gekara and Nguyen (2018) highlighted that enterprise skills such as critical thinking, creativity, problem-solving and overall digital mindset and awareness will be most important in the future, specially in ports. Jensen and Knagaard (2020) highlighted six core personal values which have a strategic importance to Danish maritime industry. These values are commitment and engagement, curiosity, spirit, social competence, innovativeness and holistic approach. Kilpi et al. (2021) emphasised that competences related to problem solving and innovativeness, environmental regulations and technology and production methods and automation are among the top competences with high importance in the future of maritime logistics. Bottalico (2021) also highlights that port labour will require advanced skills that align with digital transformation and the automation processes.

6 Concluding Remarks

This chapter has aimed at projecting the skills required in maritime logistics for the next decade. This aim was made having critically examined a few key global and industry-based challenges and identified opportunities in a way that the maritime industry could capture and fulfil their potentials over the years ahead. This chapter has also attempted to apprehend the major dimensions that could have an impact on the current and future status of maritime logistics, in particular, in the light of the dynamic and disruptive global events. Finally, it has offered an overview of essential and necessary skills for future jobs in the industry being regarded critical in achieving a sustainable and stable business entity.

The history vindicates that human beings have always sought a way to respond to the (un)expected challenges described in the previous sections. Adaptability seems to be ever more critical when projecting the future. This is particularly true in the business world including the maritime logistics industry. Maritime business is volatile in nature, largely due to the fact that the supply side is clumsy (Ma, 2020). This very nature of volatility becomes even more capricious and unpredictable by the currently ongoing pandemic, causing the maritime business world to be exposed to the greater uncertainty. The historian Arnold Toynbee (1889–1975) in his famous *A Study of History* (1934–1961) book describes this human history as a never-ending process of challenges and responses. While fully acknowledging the uncertain nature of unexperienced territories, the chapter makes a cautious projection that, like our forefathers, those (who will be) working in the maritime logistics industry would adjust their workforces in line with technology development and transform the industry into an ongoing entity becoming more crucial to our daily life now and in the future.

Management Perspective on the Transitional Decade for Maritime Logistics

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> Any time there is change, there is an opportunity. So, it is paramount that an organisation gets energised rather than paralysed.—Jack Welch, CEO General Electric

Maritime logistics is the backbone of the long supply chain. As the conveyor belt that connects continents, it plays a vital role in creating the standards which are required for the functionality of the wider supply chain.

At the turn of the century, I was a young executive working in Germany at the Hamburg Süd headquarters. Being part of a quickly growing company was exhilarating. For Hamburg Süd, the early 2000s was a time where digitalisation was taking root, and I joined a project team that helped the company migrate from legacy systems to a modern IT platform. This project taught me that embracing technology isn't about the technology itself but, rather, remaining flexible and adaptable to a new way of doing business.

This experience also taught me the important lesson that digitalisation is about embracing technology to find ways to streamline and modernise the workflow processes. At the heart of all of these processes is the need for corporate cultural change. I firmly believe that digitalisation is about the empowerment of individuals. These lessons still guide me in my current practice as an advocate for change.

Organisational accountability and accepting responsibility are not about organisational structure or the executive leadership team. It is about getting every individual in an organisation motivated and engaged by providing them with the right tools and information so they make the right decisions. It is only from this solid foundation that the leadership team can develop strategies to adapt to long-awaited change which is underway in this industry.

The wider shipping industry has remained in legacy thinking and legacy systems for far too long, leaving many companies with multiple databases stuck in departmental silos. These companies are now dealing with the structural challenge of building a "single source of truth". The pandemic shocked a reluctant industry forcing these companies to rapidly change and adapt.

The requirements for working from home (WFH) have been a great catalyst for the maritime logistics industry to examine their processes and accept the need to move from "doing the process" to "managing the process". The pandemic also made clear that each company needs to have a digital strategy

(continued)

with a focus on building a culture that accepts agile management practices as a core part of their business ethos.

At sea, the digitalisation process has been a slow and steady progress which has correctly focused on safety and transparency. The adaption of Global Positioning Systems (GPS) and advanced weather routing systems has been revolutionary in creating a foundation for modern ship management.

The digitalisation in the ship to shore space is just starting. This is an exciting time to get involved with a maritime industry which is more open and interested in accepting digital partnerships and building digital ecosystems. These digital ecosystems will focus on creating a port community which works together as one to ensure a smooth flow of communication and goods from the vessels through the ports to the landside supply chains.

The pandemic has strengthened the case for digitalisation. We now all need to be advocates for the improvements in digital standards and interoperability. This will ensure the maritime supply chain can meet the challenge of becoming a sustainable industry. The strategies and concepts in this book provide the tools and knowledge to drive innovation and push collaboration to make the digital future a sustainable reality.

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Future Directions in City Logistics

Michael G. H. Bell

1 Introduction

The ongoing pandemic and the climate emergency are proving to be catalysts for change in city logistics. There is growing concern for the 'liveability' and sustainability of urban areas. Although lockdowns around the world as a result of the pandemic noticeably reduced emissions for a period, this is insufficient to halt climate change (Forster, 2021). However, the reduced traffic during the lockdowns did enable a number of cities around the world to accelerate the process of road space reallocation (see, e.g. Combs & Pardo, 2021). In the short term, this has taken the form of a proliferation of sometimes controversial pop-up cycle lanes, but the process of reallocating road space away from carriageways and on-street parking and loading zones to pedestrian precincts, cycle lanes and shared spaces has been slowly underway for many years.

City logistics has had to adapt to the changing city streetscape while also responding to the drive to reduce carbon emissions. This is being accomplished by the deployment of a range of sizes of battery electric vehicles, which are both zero emission at the point of use and quiet in operation. Although battery electric vehicles are falling in price and increasing in range, it is recognised that for the middle mile, hydrogen or hybrid hydrogen/battery electric vehicles might be required because of their greater range and faster speed of refuelling. For buses, hydrogen is now regarded as a practical replacement for diesel (Wiggins, 2021), but the sourcing of green hydrogen is not currently possible and will remain a challenge for the foreseeable future.

The pandemic accelerated the growth of e-commerce which in turn increased the use of 'click and collect' services (Gielens et al., 2020), home delivery and delivery

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to ‘smart’ lockers (lockers equipped with sensors and linked to the internet of things). The integration of conventional retail supply chains with e-commerce, referred to as omnichannel retail, has allowed stores to double up as local order picking centres, while click and collect services have increased car park turnover by reducing shopper dwell time, an important consideration in urban areas where parking is in short supply. The customer information yielded by e-commerce has enabled supply chains to better position inventory, while tracking and tracing has improved inventory transparency. The next step will see the automation of order picking brought to the store (Michel, 2020) in a concept referred to as micro-fulfillment.

The renewed emphasis on sustainability has increased interest in the circular economy, which seeks to ‘do more with less’, reduce emissions, and, in particular, reduce the amount of waste headed for landfill. The City of Amsterdam has taken a leading role by publishing a strategy (Amsterdam Circular Strategy 2020–2025) to change how the city produces and consumes, with the aim of significantly reducing both its environmental footprint and its consumption of primary raw materials (Boffey, 2020a). While the circular economy has profound implications for the design and use of products, its main consequences for logistics relate to an increased role for ‘reverse logistics’ and ‘servitisation’. Reverse logistics will help fill backhaul capacity in final mile and middle mile delivery networks, while servitisation, whereby logistics assets like vehicles and warehouses are provided as a service rather than owned, will improve asset design, reliability and utilisation.

The accelerating spread of automation, sensors and the internet of things is increasing the data intensity of supply chains and in turn increasing their vulnerability to disruption through data corruption or cyberattack. This is promoting the development of technologies like ‘blockchain’. Blockchain solutions protect data by holding copies in multiple locations (‘distributed ledgers’), requiring validation before new transactions are entered in the ledger, and encryption, leading to an immutable history past transactions (the ‘blockchain’). This helps to protect city supply chains from fraud as well as data corruption resulting from equipment or network failure. Blockchain technology is particularly significant for cold chains, as it can assure consumers of the provenance and correct handling of products (Bamakan et al., 2021) and ensure trust in collaborative deliveries (Hribernik et al., 2020).

2 Urban Form and Liveability

Concern for the ‘liveability’ of urban areas and air quality is leading to greater emphasis on urban designs that emphasise ‘place making’ (Government Architect of NSW, 2019, 2020). This often involves the reallocation of road space from carriageway, parking spaces and loading zones for vehicles to space for pedestrians and cyclists as well as locations for social activities. A well-known example of road space reallocation is provided by the superblock scheme in Barcelona (O’Sullivan, 2020). The grid layout of central Barcelona is consolidated in superblocks of nine

Fig. 1 Map showing the superblock concept in Barcelona (Source: O'Sullivan, 2020)

smaller blocks with through traffic limited to the roads bounding the superblocks (see Fig. 1). Only vehicles belonging to residents or those making pickups or deliveries are allowed access to roads within the superblocks. Within the superblocks, the road space is reallocated from the carriageway to walkway, trees are planted, junctions are converted to pedestrian plazas, vehicle speed is restricted to 10 km/h, and street furniture is added.

The need for social distancing during the pandemic has been given new impetus to the expansion of pedestrian precincts (O'Sullivan, 2020). A design competition in Barcelona to create four new plazas in place of road junctions specifies that at least 80% of the space should be shaded by trees while 20% should be permeable, of which half should be grass, to improve flood resilience. The layout is also required to give priority to children and old people. The end result will be better air quality, reduced carbon emissions and less noise pollution within the superblocks, while the increased tree cover should help counter the 'heat island' effect in summer.

This and similar schemes in other cities around the world also require a change to first and last mile deliveries. The reallocation of road space necessitates the deployment of smaller, quieter, cleaner vehicles better suited to narrow carriageways and mixing with pedestrians. Electric vehicles are not only zero emission at the point of use but quieter and better suited to low-speed environments. Figure 2 shows the electric Cargohopper tractor-trailer unit in operation in a central part of Utrecht. Note the narrow format of the vehicle to cope with the narrow carriageway, the wide tyres to cope with cobbled paving and the expanded space for pedestrians, cycles and

Fig. 2 The Cargohopper electric tractor-trailer combination in use in Utrecht (Source: https://www.eltis.org/discover/case-studies/utrechts-sustainable-freight-transport-netherlands, 26/7/21)

social activities just visible to the right and behind the Cargohopper. For a long time, Utrecht has applied a strategy of making the inner city unattractive for vehicle access, a similar concept to the superblocks implemented in Barcelona. It has been so successful that in the last 5 years, additional bike parking had to be created to accommodate the increased use of bicycles. Utrecht is now constructing a high-density, car-free residential district for more than 12,000 people (Boffey, 2020b).

One impact of the pandemic has been to significantly increase the number of people working from home, a trend that is unlikely to completely reverse when the pandemic is over (Sells, 2021). This will change the pattern of first and last mile pickups and deliveries in ways not yet fully understood. In general terms, we expect first and last mile activity to follow people, so if more are working from home in the suburbs, then more vehicle activity can be expected in suburban locations and less in the central business district.

In the longer term, we expect a blurring of the distinction between home and work with respect to location, leading to more mixed use development and less commuting. In Australia, the initial lockdown of March 2020 led to a perceptible migration from cities to outer suburbs and beyond with house prices contracting in all capital cities except Canberra despite an anticipated cyclical upswing (KPMG, 2021). However, from the second half of 2020, house prices in Australian capital cities rebounded strongly reaching levels above those predicted by KPMG (2021) before the pandemic. This prediction factors in no population growth and interest rate reductions. One plausible explanation for the rebound in house prices is that some of those with good and stable incomes who have not migrated from capital cities are seeking more space for working from home. If this explanation is correct, it adds to the evidence that increased working from home is here to stay.

3 Omnichannel Retail

The advent of e-commerce, brought about by the development of the internet for commercial use and the development of consumer-friendly browsers in the 1990s (E-commerce Nation, 2016), initiated a fundamental change in retail. At first, e-commerce channels developed alongside the conventional channels. However, the advantages of integrating the conventional and e-commerce channels could not be ignored. Where inventory can be shared or moved between the two channels, savings in inventory cost can be achieved. Moreover, customer data garnered through online transactions can lead to better ordering and positioning of products in the conventional supply chain. Stores can double up as order picking centres. This is exemplified by ‘click and collect’ services offered by most major grocery chains, whereby shoppers order online and then collect their shopping from the ‘collection counter’ at the store or from an adjacent locker.

The integration of the conventional and e-commerce channels, referred to as omnichannel retail, is transforming city logistics. E-commerce brought with it delivery van traffic adding to conventional shopping trips by car. However, ‘click and collect’ services increase the efficiency of use of parking places at stores by reducing shopper dwell times, boosting turnover at local stores where parking places are in short supply. Difficulties in making home deliveries, caused by the need for someone to be at home to receive the delivery, can be countered by pickup at the local store or by the use of lockers, which can be situated near stations for the convenience of public transport commuters. Lockers are becoming ‘smarter’ by equipping them with sensors and linking them to the internet, thereby improving the security and efficiency of their use. Figure 3 shows smart lockers outside a store in Sydney.

In urban and suburban settings, where rapid home delivery is required by the customer, this can be outsourced to cycle delivery firms like Deliveroo or rideshare operators like Uber. Bike couriers are a growing feature of urban traffic, increasing the use of cycle lanes and reducing the need for vans and on-street loading zones. Electric bikes and electric quadricycles, like the Armadillo, can penetrate pedestrianised zones and use cycle lanes. Being battery electric vehicles, they are zero emission at the point of use, quiet and move at speeds compatible with shared spaces.

The outsourcing of transport, particularly at the micro end of the logistics spectrum, brings with it safety and social problems that have yet to be fully resolved. While self-employment undoubtedly provides flexibility in working time to drivers who may be studying or holding down other jobs, it also opens them up to exploitation, particularly where self-employment is the main or only source of income. They may not be entitled to paid leave or other social and health benefits

Fig. 3 Smart lockers outside a store in Sydney (Source: Own photo, 24/1/21)

that employment would give them. They may also undercut their employed counterparts, both by being unorganised, in the sense of not being unionised, and by avoiding social security contributions. Gradually, however, employment law is catching up with the ‘gig economy’, and in some sectors the self-employed work force is organising to bargain for better pay and conditions.

4 Electric Vehicles

Regarding the shift to net zero modes of freight transport, there is a lively debate about whether battery electric vehicles or hydrogen electric vehicles are most appropriate. In general terms, when one starts with electricity, battery electric vehicles are more than twice as energy efficient as hydrogen electric vehicles, because the production of hydrogen from water by electricity consumes energy. However, battery electric vehicles require time to recharge and suffer from limited range due to the low energy density of batteries. For a fully laden 40 tonne truck, just over 4 tonnes of lithium ion battery are needed for a range of 800 km, compared to 220 kg of diesel (Li, 2021). By contrast, trucks powered by hydrogen fuel cells have a similar driving range to diesel trucks and can be refuelled almost as rapidly, making them more suitable than battery electric vehicles for longer haul freight transport.

Apart from range, cost is another important factor. In the case of the battery electric vehicle, there is the cost of the electricity (typically low when compared to other fuels, like diesel) and the cost of the battery (typically high but falling rapidly as lithium ion battery production ramps up around the world). In the case of the hydrogen electric vehicle, there is the cost of hydrogen (currently high but likely to fall as production increases) and the cost of the fuel cell to convert the hydrogen into electricity (also high but likely to fall as production increases). The cost of the vehicles plus electric motors would be common to both types of electric vehicle and therefore not relevant in a cost comparison. However, it is worth noting that the cost of maintenance is much lower for an electric vehicle than for a comparable diesel vehicle, as the former has fewer moving parts and does not need oil changes.

In addition to the vehicle costs, there is the cost of the infrastructure for recharging or refuelling. In the case of battery electric vehicles, there is the need for charging points. For freight vehicles, these are likely to be located in depots. Where fleets are charged overnight, modifications to the electricity grid are required to support the load. There has been considerable research on smart electricity grids, which seek to balance electricity demand and supply in an intelligent way, charging batteries when electricity is abundant and potentially also drawing on batteries to stabilise the network during periods of high electricity demand in other sectors. These batteries may be part of domestic solar energy systems or embedded within commercial and private vehicles plugged in for recharging.

For hydrogen electric vehicles, there is a need for investment in a network of refuelling stations, which will depend on demand for hydrogen as well as the existence of a supply chain for hydrogen. Supply chain challenges are discussed later. The few hydrogen refuelling points available to date have been integrated with conventional petrol/diesel refilling stations.

The extent to which hydrogen is a carbon neutral fuel depends on how it is sourced. ‘Grey hydrogen’ is produced by methane steam reforming and is in essence no different from a fossil fuel unless the methane is sourced from biomass rather than from natural gas (methane is the primary component of natural gas). Obtaining methane from biomass offers an attractive opportunity to dispose of forms of waste, typically food and agricultural waste. However, if methane is to be produced on an industrial scale, food and agricultural waste is unlikely sufficient, so crops may need to be grown for the purpose, effectively competing with food production. Methane is in any case a problematic fuel, as it is a potent greenhouse gas and far more damaging in terms of global warming than carbon dioxide per unit mass.

At present, most hydrogen is ‘grey hydrogen’ and therefore does not count as a carbon neutral fuel. The alternatives are ‘blue hydrogen’ and ‘green hydrogen’. Blue hydrogen is like grey hydrogen except that the carbon dioxide generated by the methane steam reforming process is captured and stored. However, carbon capture and storage are currently regarded as problematic and not yet practiced on an industrial scale. Green hydrogen is produced by electrolysis, whereby electricity, sourced renewably, is passed through water splitting the water molecule into hydrogen and oxygen. Renewable energy sources are primarily wind turbines and solar cells but could also include hydro or tidal projects. There are plans for large green hydrogen production plants in Australia and Saudi Arabia, where wind and sun are plentiful.

In addition to issues with the sourcing of hydrogen, there are supply chain challenges. Hydrogen is a very light gas, but it can be liquified, compressed or chemically combined for transport and storage. Liquifying hydrogen requires cooling it to −253 °C, which in turn involves consuming around a third of the hydrogen in the process of refrigeration. Alternatively, hydrogen can be compressed to around 700 bar. For long distances, the conversion of hydrogen into ammonia by combining it with nitrogen in the atmosphere leads to a gas which liquifies at −33 °C (or at room temperature at pressures of 8 to 10 bar). Hydrogen can then be extracted from ammonia by thermal catalytic decomposition or an electrochemical process. Dangers relating to the handling and storage of hydrogen are that it can leak through steel due to its small molecular size, is explosive when mixed with oxygen and burns with an invisible flame. Both the process of converting hydrogen into ammonia without generating carbon dioxide and the process of extracting hydrogen from ammonia have yet to be demonstrated at an industrial scale (Service, 2018).

The resolution of the battery versus hydrogen debate seems to be that both types of electric vehicle have a role. Where range is smaller, battery electric vehicles have the edge, both for small vehicles, like electric cargo bikes, and for larger vehicles, like refuse collection trucks. Where longer range or rapid refuelling is required, hydrogen electric vehicles would be the better choice. Hydrogen has already been identified as a practical zero-emission fuel for buses, and a number of hydrogen buses are in use in a range of countries. Where the range required of vehicles is uncertain, the case for hybrid battery-hydrogen electric trucks has been made, using hydrogen when the batteries are insufficient to return to the depot for recharging. Fleets of battery electric vehicles are already being deployed for local delivery, for example, by Ikea and Australia Post in Australia.

In response to road space reallocation and ‘place making’ in urban areas, two-echelon distribution networks operated by electric vehicles are evolving for parcels. A good example of this is the DPD parcel operation in London, which uses a range of electric vehicle sizes, shown in Fig. 4. The larger electric truck is used to connect the satellite in the central area with a depot on the edge of the city, while the smaller vehicles perform pickups and deliveries in areas that could be difficult to access with the larger truck. The Cargohopper mentioned earlier is also part of a two-echelon solution, with delivery to a depot on the outskirts of Utrecht from where last mile delivery is performed by the Cargohopper.

5 Circular Economy

Along with increasing concern about emissions and air quality, there is a growing concern about the amount of waste going to landfill or incineration as well as the depletion of finite natural resources. Attempts to recycle waste are at an early stage of

Fig. 4 A range of electric vehicles deployed by DPD in a two-echelon parcel pickup and delivery operation (Source: https://postandparcel.info/117689/news/parcel/dpd-cyber-weekend-parcel-volumes-up-13/, 1/8/21)

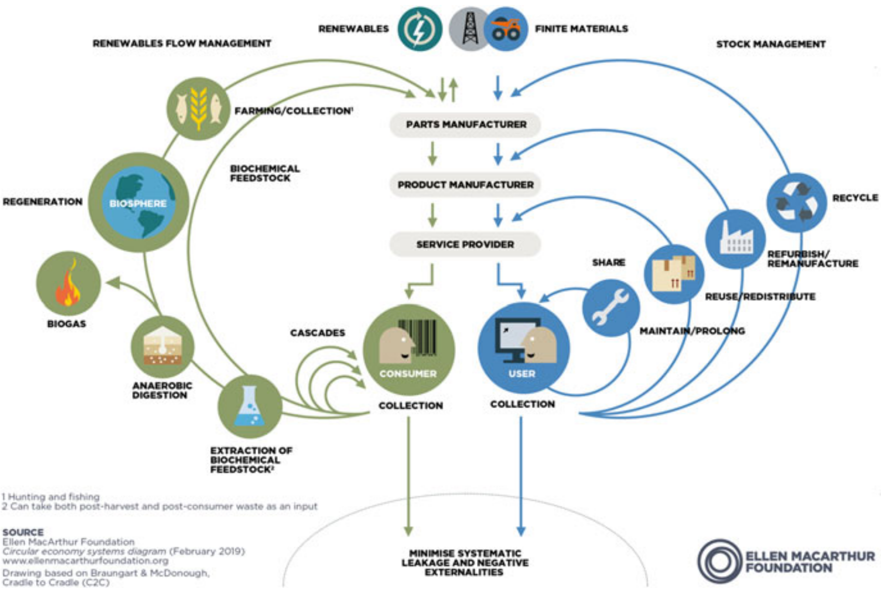

Fig. 5 Infographic depicting the circular material flows behind the circular economy (Source: https://www.ellenmacarthurfoundation.org/circular-economy/concept/infographic, 1/8/21)

development in many cities around the world, given the opportunities that exist. The scope of the circular economy has been depicted in the well-known Ellen MacArthur Foundation infographic reproduced in Fig. 5. The right half of the infographic relates to the sharing, maintenance, repair, reuse, refurbishment and recycling of manufactured products, while the left half relates to the processing of biomass into fuel, feed stocks and organic materials for use in industry.

The circular economy has important implications for the design and manufacture of products (NSW, 2018). Products should be designed considering their life cycle and, where possible, be made from recovered materials. They should consist of modular components which allow easy repairs and upgrades. This presents opportunities for innovative product design. End-of-life products should be returned to the retailer, distributor or manufacturer for refurbishment, disassembly, recycling or safe disposal. Business models should be devised to facilitate product sharing to maximise their use and designed for reliability and ease of repair. To some extent, this already happens in the white goods sector, where an old refrigerator, for example, is returned with the delivery of a new refrigerator, along with the packaging material.

Moves to greater circularity in cities imply more 'reverse' logistics to return items, like bottles for the reuse of glass, plastics for the production of oil and new plastics, equipment returned under warrantee and end-of-life products like refrigerators being returned to their suppliers. There has been a move to extend producer responsibility legislation in some countries to require producers to take back their products at the end of their useful lives for disassembly, recycling or safe disposal (OECD, 2006).

More reverse logistics has in turn the potential to improve the efficiency of logistics in general by filling backhauls that would otherwise go unfilled. In some cases, the connection is direct, for example, when a replacement part or piece of machinery is delivered, the old item can be returned to the manufacturer on the same vehicle. In other cases, the connection is less direct, for example, the use of the delivery vehicle from distribution centre to store can be used to remove the packaging and waste for recycling by a third party on the return trip, forming a triangular tour.

The circular economy also influences business models and the design of products (Han et al., 2020). 'Servitisation' is encouraged, whereby the business model is based on selling a service provided by a product rather than selling the product itself. This in turn encourages the design of products that are more reliable and easier to maintain or repair. Legislation to extend producer responsibility is likely to have a similar impact on the quality of products, as producers would not wish to receive back their products early, and when the product is returned, they would like to be able to disassemble it and repair, recycle or dispose the parts as cost-effectively as possible.

Key to shifting supply chains from an open loop make-use-dispose approach to a closed loop reduce-reuse-recycle approach is a combination of regulation and market incentives, whereby regulation sets the rules within which the market functions. The climate emergency is likely to lead to greater regulation that favours circular activities.

6 Digital Supply Chain Security

Underlying advances in city logistics are gradual improvements in sensors and labels, which increase the visibility of inventory in the supply chain, help to improve reliability and reduce inventory cost (more 'just in time' and less 'just in case'). The consequence has been better supply chain reliability and responsiveness to disruptions. An important aspect of improving supply chain reliability and safety has not only been the greater availability of data as a result of the networking of 'smart devices', referred to as the internet of things (IoT), but also advances in the way data is held (DHL, 2018). The advent of 'blockchain' solutions has made certain kinds of fraud more difficult and also improved the resilience of the cybernetworks which support supply chains to malfunction or attack.

Blockchain solutions involve holding copies of the ledger in multiple locations, referred to as 'distributed ledgers', combined with encryption to create an immutable record of past transactions, referred to as the 'blockchain'. Holding the ledger in multiple locations helps guard against fraudulent changes or data corruption as differences between copies of the ledger become easily identifiable. Adding to the ledger requires validation; however once validated, the new ledger entrant is encrypted and added to the blockchain.

Application of blockchain solutions in supply chains is widespread. Examples include the meat supply chain, where provenance and correct handling is important for quality and consumer safety. As meat passes from paddock to plate, it passes through a number of stages from farm to slaughterhouse to cold storage to distribution centre to retailer, and at each stage there are requirements for checking, temperature control, sanitation and packaging leading to a number of control points where records must be kept. The consumer would like to be assured that the product successfully passed each control point and that the opportunity for data manipulation or error at any stage is eliminated or minimised. Blockchain solutions can go a long way to providing this assurance. The pharmaceuticals industry is another sector where provenance and correct handling is of utmost importance to the consumer.

The spread of automation in warehouses is multiplying the quantity of data involved in tracking and tracing products. While automation may go some way to reducing human error in data entry, it also increases the importance of data security. Data corruption through technical malfunction or cyberattack can lead to significant supply chain disruption as system knowledge is no longer embodied in human experience and memory. An example of this vulnerability has arisen on a number of occasions in maritime container terminals when terminal operating system upgrades have led to the corruption of the database of container location and status in the yard, resulting in months of disruption as 'lost' containers are relocated. In Australia, prominent logistics service providers TNT and Toll have recently suffered significant disruptions due to cyberattacks (Perrot, 2017; Smith, 2020). Blockchain solutions can provide the higher level of data security required by greater automation.

7 Conclusions

The confluence of the pandemic and the climate emergency is reshaping city logistics at an accelerating pace. The motto of 'build back better' is associated with changes to street layout that enhance 'liveability', but this also creates challenges for city logistics. Less street space for vehicle carriageway and loading zones and more for pedestrian precincts, cycleways and shared space are requiring the deployment of smaller, quieter, cleaner vehicles for first and final mile pickups and deliveries in denser urban areas. Battery electric vehicles are ideal for this niche as they create zero emissions at the point of use and are quiet.

Retail is also changing with the growth of e-commerce, 'click and collect' services, home delivery and the use of 'smart' lockers. From a logistics perspective, the advance is the emergence of omnichannel retail, where inventory is moved between channels guided by better prediction of customer demands and facilitated by greater inventory visibility. This, in turn, is facilitated by new sensors, tracking and tracing, and the internet of things. Stores increasingly double up as order picking centres.

Along with greater concern for the environment, air quality and vehicle emissions comes increased interest in 'doing more with less' and reducing the amount of waste going to landfill. This has profound implications for the urban economy and supply chains, starting with the way products are designed. By designing products to last longer, to be easier to repair when they fail and to facilitate recycling at the end of their useful lives, it is possible to reduce both the amount of waste going to landfill and the finite resources consumed in their production. Regarding logistics, this implies an increase in 'reverse' logistics, where products are returned to the retailer, distributor or producer. This has the potential to provide backhauls for the first and middle miles of logistics, improving vehicle utilisation.

Advances in sensors, the 'internet of things' and automation, while improving supply chain transparency and efficiency, also multiply the data and increase supply chain vulnerability to disruption as a result of data corruption or cyber attack. Blockchain technology is offering improved data security by holding copies of the 'ledger' in multiple locations and encryption to produce an immutable history of transactions, the 'blockchain'. This increases supply chain resilience not just to failures but also to fraud and cyberattack. As retail becomes increasingly data driven, data security is becoming an increasingly important aspect of city logistics.

Management Perspective on the Future of City Logistics: A Professional Perspective

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Ecommerce has seen a steady growth over the last decade, and with COVID-19 we have seen accelerated growth over the past 16 months. The increase in ecommerce is creating its challenges, such as delivery vans scrambling for limited curb space. We can see a paradox of avoiding traffic by ordering online, creating the traffic jams we want to avoid. Though online shopping is convenient, the often impulse-buy single item purchases are far less traffic efficient as single car trips to the mall to make multiple purchases.

Many of the developments described in this chapter are taking shape and are helping to ease the challenges the growth of ecommerce has created. The multi-echelon approach can take different shapes; smart lockers are on the increase and are in its own way a multi-echelon delivery solution. The difference is that the last leg is carried out by the receiver. We are also seeing an increasing number of businesses moving to night-time delivery, using the quiet traffic hours to their advantage; however this approach is not feasible for all customers.

The circular economy is slowly taking shape; in the white goods sector (home appliances), it is becoming standard practice (if not already regulated) to collect your old fridge, stove, etc. on delivery, including returning the packaging material back to the depot for recycling.

There is a lot of talk about autonomous vehicles as well as drones. I don't expect a huge uptake of drones in city logistics any time soon. However, once operational, autonomous vehicles will open a range of new opportunities for last mile, specifically in a multi-echelon concept, though I believe we'll see that the last 50 meters will still be managed by a delivery person.

In the short run, the future of city logistics will depend on the use of technology. The Australian Productivity Commission report released on 17 June 2021 shows the decade ending 2019–2020 was the worst decade of growth in 60 years. The good news is that there are many technological developments and solutions available already that support city logistics by increasing productivity. The efficient running of city logistics will evolve around the use of solutions such as route optimisation, integrated with execution management tools to dynamically manage last mile under changing circumstances and requirements. New businesses have evolved based on such technology, such as Uber, Deliveroo or a lesser-known business like Go People. Many existing players in the industry have started using such tools as well, but a surprisingly large number of businesses still manage the final mile "on the back of a napkin". The biggest productivity improvement in the short term will be achieved by employing available technology now.

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Recent Advances of Service Supply Chain Management: Roles of Logistics

Tsan-Ming Choi

1 Introduction

Today, in the digital platform era, the service industry is influential in all developed countries and markets. In economics, service industries are traditionally called the "tertiary industries." Examples of service industries include on-demand platforms, travel and tourism, information technology (IT), transportation and logistics, entertainment, media, sports, healthcare, finance, consulting, energy, retail, etc.[1] In terms of business volume, the service industry is definitely a huge sector. IndustryWeek reports that "*Service sector business currently accounts for about two-thirds of the U.S. Gross Domestic Product, and about 8% of economic growth.*[2]" If we narrow down a bit and focus on the global professional services (Harvey, 2016) market (GPSM), Business Wire reports that the GPSM reached a value of more than US$5700 billion in 2018 and will exceed US$8000 billion by 2022.[3]

On the other hand, supply chain management (SCM) is a business area which is well-established. Service supply chain management (SSCM) is related to SCM with

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[1] https://simplicable.com/new/service-industry (accessed 4 January 2021).

[2] https://www.industryweek.com/finance/software-systems/article/21958424/services-supply-chain-management-an-untapped-opportunity (accessed 4 January 2021).

[3] https://www.businesswire.com/news/home/20190701005419/en/The-2019-Global-Professional-Services-Market%2D%2D-Worth-5.7-Billion-in-2018-Projected-to-Surpass-8-Billion-by-2022%2D%2D-ResearchAndMarkets.com (accessed 4 January 2021).

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Table 1 Examples of SOSCs and PSSCs

Types of SSCs	Examples
SOSCs	Tourism, IT, finance, etc.
PSSCs	Retailing of physical products, design of physical products, logistics (including inventory and warehousing) and transportation for physical product production systems, etc.

a special focus on services (Choi, 2016b). If we google the meaning of service supply chains (SSCs) and SSCM, we find the following: "*The service supply chain is the part of the supply chain dedicated to providing service on products. It addresses the supply of parts, materials, personnel and services needed to provide timely and effective product service, such as repair and maintenance.*[4]".

From the above, we understand that naturally SSCM relates to services and hence industries such as logistics, information technologies, healthcare, retailing, etc. are all directly relevant. However, must SSCM include physical products or not?

In this paper, we follow Wang et al. (2015) to define SSCs into two types, namely, the service only supply chains (SOSCs) and product-service supply chains (PSSCs). For SOSCs, physical products do not play a significant role. For PSSCs, both physical products and services are present together and are critically important to the supply chains. Examples of SOSCs and PSSCs can be found in Table 1.

There is no doubt that SSCM is an important area. In particular, achieving channel coordination for service supply chains in a global context is challenging. In this paper, we provide an updated review of the SSCM-related literature and propose an agenda for further studies. To be specific, we first review the recent operations research (OR)/operations management (OM) literature (from 2016 to 2021) for the papers highly relevant to SSCM. We then discuss the role played by logistics for SSCM and what skills logistics professional should be equipped with. Based on the observed industrial practices and the identified research gaps, we establish a research agenda.

As a remark, in Wang et al. (2015), the authors have already well-explored the literature of SSCM from the perspectives of SOSCs and PSSCs. This paper would hence first provide an update of the related fields by searching the literature from 2016 to 2020. (P.S.: The searching was conducted in December 2020.) For the related literature review, we do not aim to be exhaustive. Instead, we try to focus on the mainstream OR/OM journals listed in Web of Science.

The remaining parts of this paper are organized as follows. Section 2 reports the review of the selected literature. Section 3 discusses some industrial related observations, inputs, and findings. Section 4 presents the future research agenda. Section 5 concludes this study. To enhance presentation, a list of notation is included in Table 2.

[4] https://searcherp.techtarget.com/definition/service-supply-chain (accessed 4 January 2021)

Table 2 Notation table

Notation	Meaning
AI	Artificial intelligence
CCS	Cold chain service
CSR	Corporate social responsibility
GPSM	Global professional services market
IT	Information technology
O2O	Online-to-offline
OM	Operations management
OR	Operational research
OSS	Online subsidy service
PSSC	Product-service supply chain
SC	Supply chain
SCM	Supply chain management
SOSC	Service-only supply chain
SQG	Service qualtiy guarantee
SSC	Service supply chain
SSCM	Service supply chain management

2 Literature Review

2.1 SOSCs

Logistics services and the respective supply chains are commonly regarded as an example of SOSCs. In the literature, Liu et al. (2017b) discuss the capacity procurement challenge in logistics SSCs with demand information updates. The authors also examine the "rational expectation behavior" in the SSCs. Liu et al. (2017a) study the optimal scheduling challenge in logistics SSCs. The authors consider the presence of time windows as well as other critical demand requirements. To solve the problem, the authors first convert the multi-objective optimization model into a single-objective problem. Then, they use a genetic algorithm-based approach to find the solutions. Du and Han (2018) theoretically examine the optimal "service quality guarantee" (SQG) decision in logistics service providing supply chains. The authors highlight the importance of fairness concerns. Liu et al. (2018a) conduct a real case analysis on port SSCs. The authors report a case in Tianjin to highlight the influences brought by the overconfidence behaviors. They also consider the importance of demand information updates. Liu et al. (2018b) analytically study the optimal allocation of orders in logistics SSCs. The major factor under investigation is the fairness concern among channel members. The authors employ a multi-method approach, with empirical data from a logistics company in China, to enhance research rigor. Wang et al. (2020) study the use of blockchain for port service operations. The authors build a novel framework which helps enhance port operations efficiency by using blockchain.

In the sharing economy era, we also have many emerging new service business models in the SOSCs. Boysen et al. (2019) examine and review different matching problems in service operations in the sharing economy era. The authors further discuss the parking space sharing problem. Choi et al. (2020) analytically model the "on-demand-service-platform" operations for businesses such as Uber. The authors consider the case when the service agents are hired by the platform and consumers are risk sensitive. They uncover the value of using blockchain in the respective operations.

Other SOSC-related studies include the following: Bian et al. (2017) analytically explore the service outsourcing challenges. The authors focus on uncovering how different power structures in the supply chain would affect the optimal decisions. Zhang et al. (2018) study the optimal corporate social responsibility (CSR) and quality decisions in a service system. They propose different scenarios for service systems and identify the optimal policies by conducting simulation experiments.

2.2 PSSCs

In e-commerce, Chen et al. (2016) investigate how power structure affects the O2O retail supply chain. The authors explore the retail-led, manufacturer-led, and Nash bargaining models. Xu et al. (2018) study the O2O retail SSC system with the focal point on "online subsidy services (OSSs)." The authors argue that OSSs are commonly adopted by many e-tailers to enhance online sales. They derive the optimal OSS policies. Zhang et al. (2019b) analytically explore the optimal consumer returns policy in an online-offline channel. The authors study the case when the physical product is bundled with some services. They derive an "approximate" algorithm to determine the optimal product quantity in the PSSC. Jiang et al. (2020b) theoretically investigate the omni-channel supply chains with the considerations of retail services. The authors derive the equilibrium decisions on product pricing. In particular, they highlight the importance of offering the "buy-online-and-pickup-in-store" model. Liu et al. (2020) study e-commerce-based supply chains for fresh produce merchandise. The authors consider the presence of "freshness-keeping effort" as well as "value-added service." They find that information sharing can be beneficial to the e-tailer if it is willing to contribute its private information when the freshness elasticity threshold is sufficiently large. Qin et al. (2020) explore the logistics service policies for e-markets. The authors examine the use of different selling models (e.g., e-platforms) and consider the scenario in which the logistics service is offered by different parties. The authors interestingly show that the supplier's preference in fact aligns with logistics service enhancement.

After-sales and maintenance services are important in business operations of PSSCs. In the literature, Zhang et al. (2019a) analytically investigate the after-sales services in supply chains which commonly involve physical products. The authors consider the presence of an information sharing scheme in the PSSC. They show that information sharing need not imply that Pareto improvement can be achieved between the supply chain agents. They interestingly show that improving the forecasting accuracy may bring harms to both the retailer and manufacturer. Jiang et al. (2020a) study the optimal maintenance service policy for a production supply chain system. The authors consider the case in which quality decision is also important. They propose a cost-sharing and performance-based method achieve supply chain coordination. Ullah et al. (2020) explore the "after-sales maintenance" services in PSSCs. The authors study the scenario in which the risk-averse behaviors in the service system would affect the "free-replacement renewing warranty" policy. Zhang et al. (2020) explore the optimal "warranty service outsourcing" policies in online-offline supply chains. The focal point is on who should undertake the warranty service.

In logistics systems with physical products, Wang et al. (2016b) examine the humanitarian system and the corresponding service outsourcing decisions. The authors identify the conditions governing the proper deployment of different policies for different kinds of necessary relief supplies. Schiffer et al. (2020) conduct a case-based analysis for the optimal planning of "electric commercial vehicle fleets." The authors consider a multiple-period problem and establish a new metaheuristic method to identify the optimal routing solution. They interestingly identify the conditions in which electrification of "mid-haul logistics fleets" is a wise decision. Yu et al. (2020) study the fresh produce supply chain with "cold chain service (CCS)" decision. The authors consider the case with multiple competing retail buyers. They show that the retailer's payoff can be improved when the competing retailer is vertically integrated with the supplier if the level of "product substitutability" is sufficiently low. See Choi (2020d) for some discussions on logistics systems engineering and some recent developments in the field.

For supply chain contracting in PSSCs, Cai et al. (2017) study the contracting mechanism under vendor managed inventory (VMI) for the case when demand relates to service. The authors explore several contracts, namely, the (i) "all surplus products sponsorship" policy, (ii) "unsold inventory sponsorship" policy, and (iii)"target sponsorship" policy. One interesting finding is on how these policies may improve service levels in the VMI supply chains. Liu et al. (2016) theoretically investigate how the options contract can be applied in a delivery SSC. The authors establish the analytical model based on a revised newsvendor model. They prove that with a carefully designed options contract, the overloading problem in the SSC can be dampened.

Channel leadership and optimal supply chain structure is an important topic. He et al. (2018) explore the influence of different decision sequences on supply chains with service requirements. The authors focus on the case when the supply chain yield is stochastic. They prove that supply chain members can attain a higher payoff in the manufacturer-led game, compared to the supplier-led and Nash game counterparts. Chung et al. (2020) study the optimal structure for supply chains in which demand is service level dependent. The authors prove that a hybrid supply chain structure becomes the Nash equilibrium outcome if (i) the considered “two products are moderately substitutable” and (ii) the manufacturers are not symmetric in terms of efficiency of service enhancement. Dong et al. (2020) investigate the leadership problem for a two-channel system. The authors focus on the case when the retailer makes decisions on the optimal retail service level. They decide the conditions governing the optimality of each leadership scheme. Some channel leadership studies adopt a multi-method approach to study SSC operations. Li et al. (2016) examine the optimal decision on who should offer the needed services in the supply chain system. To enhance research rigor and offer more insights, the authors report both empirical and analytical proven results.

Some PSSCs are complex and require efficient algorithms to find the optimal solutions. In the literature, Hong et al. (2018) computationally study the optimal design for a supply chain selling environmentally sustainable product. The authors build the models for the case when the service time is guaranteed. They solve the problems via a computational approach using the “particle swarm optimization (PSO)”-based methods. Liu and He (2018) study logistics SSCM with four different decision-makers, namely, “logistics service subcontractors,” “logistics service providers,” “logistics services integrators,” and “logistics service demand sides.” The authors derive the equilibrium conditions and build the “finite-dimensional variational inequality” model. They solve the problem with the use of a novel “smoothing self-adaptive L-M algorithm.” Nagurney and Dutta (2019) study blood product-service supply chains. The authors adopt the “generalized Nash equilibrium” approach. They solve the problem via using the variational equilibrium method.

A common example of PSSC is the publishing supply chain. Zhao et al. (2017) theoretically explore the publication supply chain and explore three commonly seen operational models, namely, the “subscription-based model,” “advertisement-sponsored model,” and a mix of the two. They find that advertisers may not obtain their best benefit when the publisher adopts the optimal policy for itself. This inherent conflict is substantial.

2.3 Others

Note that in the literature, there are also a few discussion and review papers which examine SSCs. For instance, Stavrulaki and Davis (2014) review the service science literature. The authors put emphasis on the service delivery mechanism and build a classification scheme for SSCM. Choi et al. (2016b) discuss risk management problems in SSCs. They focus their discussions on areas such as logistics and the use of information. Galetsi and Katsaliaki (2020) examine the prior studies that explore applications of big data for healthcare operations. Roy et al. (2020) report a comprehensive literature review on healthcare logistics. We refer interested readers to them for the respective details.

3 Roles of Logistics and Industrial Practices

3.1 How Logistics Affects Services SCs

From our literature review above, we find that logistics is critical to service supply chains. For SOSCs, the optimal offering of logistics services and setting up of logistics systems (e.g., with logistics capacity and demand information updating (Liu et al., 2017b)) are essentially important. For PSSCs, an optimal deployment of logistics supports the whole SC system. For example, in e-commerce, without logistics, the products cannot be delivered to the right place at the right time correctly. In fresh produce retail supply chains, logistics is crucial to ensure the fresh agricultural products are available at the retail sales floors.

In the industry, since business operations are in the digital age, it is important to examine how information technology (IT) affects logistics and its utilization for SSCM. For example, in DHL and UPS, these logistics service providers are forming alliances with their clients (e.g., manufacturers) to have information sharing. The use of IT is hence crucial to ensure correct and timely information is shared. The SSC is also more transparent, and the enhanced visibility can improve operational planning and decision-making for all members of the SSCs.

In the COVID-19 era, logistics is the "Messiah" as lots of business models rely on it. The "bring-service-to-your-home" policy, in which private tutors use a truck to host their school to make it a mobile service for individual students, is an example (Choi, 2020c). Another well-known example is in food delivery which becomes the much-demanded business model for everybody around the world when there are measures for city lockdowns.

The above real-world industry-related issues highlight how logistics affects SSCs.

3.2 Research Skills Needed by Logistics Managers

Service supply chain operations have entered the digital age. Some necessary skills needed by logistics and SC managers nowadays include the following:

SCM Knowledge As the job requires, logistics managers must be knowledgeable in SCM, which is necessary (but may not be sufficient). Common knowledge, such as the importance and values of forming alliances with supply chain partners, is basic and essential. For example, on DHL's website,[5] we can find the following quote: "*At DHL we understand that dynamic technology markets demand dynamic solutions. So we seek strong partnerships with every customer, envisaging and creating the connections to achieve business success. You can rely on our unrivalled global reach, experience and engagement. We'll help you to imagine and enable new*

[5] https://www.dhl.com/global-en/home/industry-sectors/technology.html (accessed 4 January 2021)

approaches and solutions. Together we will push the pace of change. And always we will enrich your experience with our industry-leading logistics services." Other needed knowledge include the use of information for SSCM and the significance of incentive alignment schemes.

Technological Readiness Drones, AI, big data analytics (Shen et al., 2019), blockchain (Choi & Luo, 2019; Choi et al., 2019b), etc. are all technological jargons that we come across every day. However, they are not just some "buzz words" because they are actually a part of real practices. If we look at logistics companies such as DHL, FedEx, and UPS, these disruptive technological tools are all in their agenda (Choi et al. 2022). So, logistics and supply chain managers must be technologically ready in order to survive.

Sustainable Logistics For the long-term development and survival of human civilization, we need to pay attention to sustainability and the environment. In the literature, there are proposals on extended producer responsibility (Cai & Choi, 2021) as well as extended consumer responsibility (Sheu & Choi, 2019). This is in fact needed by many SSCs operating in all parts of the world. Thus, logistics managers should be able to work with their clients for sustainable logistics. In the real world, DHL has several sustainable logistics-related services and programs, such as the "carbon emission reporting" and "carbon offsetting."[6]

New Normal After facing the COVID-19 pandemic for the entire 2020, business operations and people all around the world have established a lot of "new normal" (Ivanov, 2020b; Ivanov & Dolgui, 2020). For example, online food ordering and delivery becomes the new king. Online meetings and webinars with Zoom or Microsoft Teams are replacing many tedious physical face-to-face meetings. This will affect the future setting of conferences and workshops. Remote working (such as "home office") has been well-advocated for decades but now becomes a new normal in many industries, including education. All these new normal would bring new challenges, and logistics practices (including location and scheduling problems) are involved. On the other hand, the logistics industry itself also has some new normal. For instance, for airline operations, expectedly there are huge differences in the pre-COVID-19 and post-COVID-19 ages. Executives and operations managers of airlines should hence be equipped with risk management mindsets (Merkert & Swidan, 2019).

Lifelong Learning and Remarks Here are two important remarks: (i) The required skill sets are dynamic. As we can see from the discussions above, the proposed skills have relevance to COVID-19 as well as the current market needs (e.g., IT and sustainability). Thus, perhaps the most critical skill needed by a good logistics manager should be the ability to learn and adapt to the highly dynamic market

[6] https://www.dhl.com/global-en/home/industry-sectors/technology.html (Accessed 4 January 2021)

environment. In other words, committing to lifelong learning is the most important skill. (ii) In the literature, there are discussions on the career pattern of supply chains executives (e.g., Flöthmann & Hoberg, 2017). Interested readers can check them out.

4 Future Research Agenda

From the reviewed literature and industrial explorations, we have identified some research issues. We hence propose the respective future research directions as follows:

SOSCs In the current OR/OM literature, as revealed by our literature review above, most studies still focus more on PSSCs, and hence a lot more studies on SOSCs should be conducted. In particular, many newly emerged service business models, such as the key opinion leaders or live streamers in social media platforms such as YouTube, are related to SOSCs. More research related to them should be conducted.

SSC Coordination Achieving supply chain coordination is a fundamental topic for SSCM, while our literature review shows that there is still much room for further improvement. From our discussion with the industry as well as the review of the recent literature, we find that this topic is pertinent and deserves deep exploration. For example, with the adoption of new technologies, suppose that the whole service supply chain is benefited. However, how to share the cost and benefit between channel members in SSCs is a realistic, important, yet under-explored problem.

COVID-19 Since early 2020, the COVID-19 pandemic (Amankwah-Amoah, 2020; Ivanov, 2020a) has affected all walks of life, and the whole world has suffered. Despite spending lots of efforts on finding solutions to deal with COVID-19, much more studies should be conducted to address many related challenges to SSCM. In particular, many changes in business operations are found under the "new normal." For example, online businesses have expanded and logistics service providers become more critical than ever. Using logistics can also be a lifesaver for some service operations. For instance, Choi (2020c) reports a real-world industrial case of adopting the "bring-service-to-your-home" strategy as a way to cope with COVID-19. In addition, logistics plays a crucial role in supporting healthcare, such as storage and deliveries of vaccines (Kazaz et al., 2016; Chick et al., 2008). In general, how business operations can conduct risk analysis and establish the optimal strategy to support their service operations is a very important research area. See Choi (2021) for some more discussions on this aspect.

Roles of Technologies In the digital age, all kinds of IT tools and devices are present. Blockchain (Choi, 2019, 2020b), AI and business intelligence (Aras et al., 2020), platform technologies (Bhargava et al., 2013), and big data tools (Choi et al., 2018) are all critically important. They are also found to be important in the service industry (e.g., in healthcare and logistics). For example, FedEx has established tracking technologies to establish a competitive edge. The sensor-based system for FedEx is especially useful for healthcare services.[7] DHL and UPS have both invested substantially in the use of technologies, ranging from drones, data analytics, to package traceability tools, with the goal of providing better logistics services in a more transparent, elastic (Choi, 2020a), and responsive (Choi, 2016a) SSC. More studies should hence be conducted to provide the needed managerial insights.

On-Demand Platforms Before the COVID-19 pandemic, the concept of sharing economy (Benjaafar et al., 2018) is well-advocated as a way to enhance resource allocation and usage. Many on-demand service platforms (Wang et al., 2016a; Bellos et al., 2017; Bai et al., 2018), such as Uber (Sun et al., 2019), Deliveroo, etc., have emerged. Under COVID-19, on-demand platforms become even more important (Choi and Shi 2022). These service models all deserve deeper investigation, especially in the post-COVID-19 era.

Combining Empirical and Analytical Research Most of the reported studies in OR/OM related to SSCM are either mathematical modeling based or empirical case oriented. However, it is in fact important to combine them together, i.e., adopting the multi-methodological approach (Choi et al., 2016a). This approach can improve research rigor and make the findings more scientifically solid and sound. Impacts of the related study should also be enhanced.

System of Systems Approach In our literature review, most studies focus on exploring SSCM from the perspective of simplified supply chain systems. For many real-world established service systems, they actually form a system of systems (Choi et al., 2019a). Here, a system of systems means a very complex system in which many features are present (e.g., satisfying the Maier's criteria). In logistics and SSC systems, more research should be conducted using the system of systems approach. The application domain includes sustainable SSCM with the consideration of "sustainable logistics." The use of emerging technologies would also be critical for research of this type owing to the complexity of the respective system of systems.

5 Conclusion

Today, service supply chain management (SSCM) is undoubtedly critical. In particular, achieving channel coordination for service supply chains in a global context is a big challenge. In this paper, we have conduced an updated review of recent SSCM studies with respect to the recent operations research (OR)/operations management (OM) literature (from 2016 to 2020). After that, we have explored how, in the real

[7] https://www.fedex.com/en-us/healthcare/knowledge-center/technology/tracking-solutions-competitive-supply-chain-strategy.html (Accessed 4 January 2021)

world, logistics would affect SSCM, especially the PSSC. We have then discussed the role played by logistics for SSCM and what skills logistics managers need to be equipped with. Based on the observed industrial practices and the identified research gaps, we have established a research agenda and proposed various future research directions.

Note that this paper has a few limitations. For instance, the review of related literature is not exhaustive. This paper also tries to avoid overlapping with prior review papers (such as Wang et al., 2015), and hence some topics are intentionally skipped or made brief. Readers should kindly be careful when they interpret the findings of this paper.

Management Perspective on Skills for Tomorrow's Cruising Industry

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Before COVID-19 the international cruising industry enjoyed steady and uninterrupted growth. Between 2009 and 2019, the industry grew by 69%, according to CLIA's report *The Economic Contribution of the International Cruise Industry Globally in 2019*, contributing in 2019 over $154 billion of output to the global economy, along with over 1.16 million jobs. While the COVID-19 has brought the cruising industry (temporarily) to its knees, the future of the industry and its core fundamentals remain strong.

In particular, the luxury and ultra-luxury segments of the industry would probably experience a dramatic growth over the next few years, with 40 new ships joining global fleets between 2021 and 2026, 4 of those coming to Silversea Cruises. Smaller, more specious (in terms of space to guest ratio), and luxuriously equipped ships offer customers extraordinary experiences, like personal butlers, signature spa treatments, or culinary enrichment programs on board and ashore. The smaller ships have the ability to reach a wider range of destinations and ports that are closer to city centers, saving guests time and hassle.

The cruising industry will continue to innovate, to improve its efficiencies, and to raise the bar in terms of its environmental footprint, offering onboard and destination management. Consequently, the industry will need to attract talents with specific skills to deliver its ambitious growth and continuous transformation agenda.

Analytical and Data Science Skills

In the service industry like cruising, personalization of offers and any sort of customer interactions will be critical to drive up engagement and loyalty and, ultimately through it, sales. The data and business analytics become a driving force for decision-making, allowing leaders to make more informed decisions

(continued)

and improve efficiencies. In today's and the future world, organizations collect a huge amount of data (e.g., about customers). Being able to process the big data efficiently and effectively, present meaningful insights, or draw relevant conclusions from reporting sets will be indispensable in the future.

Emotional and Cognitive Skills

There are two main reasons why these skills will be important. One is that they are frequently overlooked by graduates who tend to focus on acquiring technical skills and core knowledge during the course of their studies. The cognitive and emotional skills development usually takes a back seat. It is those skills, however, that are likely to help the graduate to get through a job interview process and then facilitate success in the job. Being able to effectively collaborate, empathize, or communicate is more important than ever before. The second reason is that automation and AI systems will be able to replace more and more tasks that humans do these days. What AI will not be able to replace, at least in the coming years, is human emotions, e.g., ability to inspire others or build effective teams based on strong collaboration, trust, and respect. For more details, interested readers can refer to a book by E.D. Hess and K. Ludwig *Humility Is the New Smart: Rethinking Human Excellence in the Smart Machine Age*.

Digital and E-Commerce Skills

The topic of digitalization of global economy, and the cruise industry in particular, is not new. What is new is the increasing pace of digital transformation, especially following the COVID-19 pandemic. The cruise industry will need more digital and e-commerce talents to meet the growing business needs in the area: adopting latest digital innovation or catching up with competition and raising customer demands through implementing widely known technological enhancements such as e-commerce channel (website sales), new payment gateways, online or video chats, and effective social media strategies, to name a few. The digitalization of corporate environment will also take to new heights, thanks to hybrid/remote working and changing employee expectations, requiring from future employees to be digitally savvy in two ways: (a) to be able to effectively work and collaborate via digital enterprise tools and (b) to have the skills and knowledge to manage those corporate systems.

Product Development and Innovation Management

To survive is to innovate, to push boundaries, to improve, and to adopt. The cruising industry is a competitive industry. It is also an industry where customer needs and expectations evolve constantly, requiring cruise lines to be at the top of their game. As the industry grows, and competition intensifies,

(continued)

it will require sharp minds that can manage their product development pipelines. Skills such as design thinking (a human-centered approach to innovation), project and program management, and agile skills will be in high demand. The era of "big bang" product launches is almost over, and most product innovation these days becomes incremental, in small batches, through MVP (minimum viable product) concept and A/B testing.

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Competence Development, Learning and Change in Supply Chain Management

Britta Gammelgaard

1 Introduction

Digital technologies, such as administrative robots and artificial intelligence (AI), are currently transforming supply chain organisations. The goal of implementing such technologies is to increase value creation and to create more value on a strategic level. However, following contingency theory, there must be a fit between technology in use, strategy, structure and systems to secure the performance of an organisation (Graetz & Smith, 2010). This means that as technology changes, strategy, structure and processes must also change so that a fit between these features can be re-established. Because the new technologies are transformative in themselves, individual and organisational skills and competencies must go through a transformation phase, too (Pleuger et al., 2019). This requires profound organisational learning and change to an extent that has not been seen since the start of the most recent globalisation era in the late 1990s.

Obviously, companies will try—and need to—recruit recently educated employees who are 'born digital' and have the necessary analytical skills to exploit the data created by digitisation. However, this may not be enough because they may not have profound professional knowledge of supply chain management, logistics and procurement. Furthermore, such new types of employees may not have sufficient management skills, competencies and experiences needed to transform the organisation. Therefore, a thorough transformation of the SCM organisation and its processes is necessary to match the competence requirements for the future. The purpose of this chapter is to present a framework for transforming SCM competencies in a way that can create value at a strategic level and stay competitive in an era with intense technology disruptions.

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This chapter begins with an outline of what we consider the elements of transformation. Here, we are drawing on the recent literature on digitalisation in purchasing and supply management combined with the well-known literature on SCM processes. We then look into theory on process management to better understand the concept of process and capture the dynamics of competence development. Then, learning and leadership will be addressed as the drivers of competence development and, thereby, change; finally, we discuss how considering all the aspects of SCM processes ends up in a framework that may help SCM organisations in their competence development.

2 Elements of SCM Competence Development

First, it is necessary to clarify precisely what is meant by digital technologies, as well as the related concepts of digitisation and digitalisation. Here, we lean on Srai and Lorentz (2019), who outline a number of digital technologies for purchasing and supply management, which is an essential part of the theoretical concept of SCM. They list nine technologies, some of which are basic and others advanced: internet, Internet of Things (IoT), social media, cloud, big data analytics, cognitive computing and AI, mobile technologies, augmented reality, blockchain and additive manufacturing. Srai and Lorentz (2019) further make a distinction between **digitisation** and **digitalisation.** Digitisation refers to the conversion of analogue information streams to digital bits; digitisation is at the heart of the transformation process towards new value-adding organisational processes, which, in turn, is referred to as digitalisation. In this chapter, competence development is closely intertwined with digitalisation processes.

From their list of digital technologies, Srai and Lorenz (2019) outline a theory-based list of processes that the purchasing and supply organisation typically will be responsible for within their 'turf': transaction management; coordination and control; process improvement and innovation; aligned category management; supplier category assessment; relationship management; and supply market knowledge management. These processes are further identified as value drivers for the organisation, where some just reduce administrative burdens and others contribute more broadly to value creation by transcending internal borders. Combining these processes with technologies, these authors produce a digitalisation grid, hence resulting in a set of design principles for digital interventions. These are—depending on combination of technology and process—interconnectivity, decentralised decisions, technical (decision support) assistance, and/or information transparency. Creating interconnectivity is the simplest intervention, and creating information transparency is the most advanced and demanding.

Although Srai and Lorentz's (2019) model targets purchasing and supply management, several of the value drivers are also considered part of supply chain management. Therefore, we suggest combining the listed technologies with SCM value drivers—or SCM processes—as Croxton et al. (2001) identify in detail in their article 'Supply Chain Management Processes', which reports on intense collaboration with practice. The eight cross-functional and interorganisational SCM processes

SCM process / Technology	Customer Relation-ship Management	Customer Service Management	Demand Management	Product Development & Commercialization	Manufacturing Flow Management	Order Fulfilment	Returns Management	Supplier Relationship Management
Internet								
IoT								
Social Media								
Cloud								
Big Data, Analytics								
Cognitive Computing, AI								
Augmented Reality								
Blockchain								
Additive Manufacturing								

Fig. 1 SCM digitalisation grid. Adapted from Srai and Lorentz (2019) and Croxton et al. (2001)

are as follows: (1) customer relationship management (CRM), (2) customer service management, (3) demand management, (4) product development and commercialisation, (5) manufacturing flow management, (6) order fulfilment, (7) returns management and (8) supplier relationship management (SRM). All these processes have strategic and operational subprocesses and interfaces between them. All are important, but the CRM and SRM processes are of particular importance because they define the relationships in the supply chain and, therefore, are the main drivers of value.

The idea behind Fig. 1 is that companies can use and fill in the grid to get an overview of where the individual technologies can create value for an organisation's supply chain. Here, only the main SCM processes are depicted, but it should be applied to subprocesses as well by following Croxton et al.'s (2001) process framework.

In working oneself through the grid to design the competence development strategy, the company must first determine its own present position and from there outline future pathways for implementation of new technologies. Here, decisions regarding the interconnectivity between internal departments are needed, including if external supply chain partners should be involved. Second, the company will need to identify and decide how the individual technologies create possibilities for decentralised decision-making that can save management resources. Third, there is a need to identify and decide where mobile technologies may create value as decision-making devices. Finally, decisions on where and to whom information transparency will be needed are necessary.

Concretely, this means that when the SCM digitalisation grid presented in Fig. 1 is used as a management tool, the entities of transformation are defined by combining the SCM processes with one or more technologies and how value can be created. Examples would be discussions on how new value-adding processes can be established for customer relationship management through social media, demand management through big data analytics and additive manufacturing for manufacturing flow management through additive manufacturing such as 3D printing. This means that a strategic pathway can be outlined, but the model does not say anything about how to go from one state to the other. In other words, the implementation of the digital SCM strategy and how competencies should be developed is not so clear. For that purpose, it is necessary to understand the organisational processes leading to new competencies.

3 Understanding the Breadth and Depth of Processes

The deployment of new technologies requires new processes within the organisation, as well as beyond for the integration and use of data to and from customers and suppliers. To understand how to change and develop existing processes, Garvin's (1998) organisational process model is helpful; he states that at the core of every organisation, there will be **work processes**. Work processes take place in manufacturing and in services such as distribution and administration. Work processes are often depicted as sequential steps in the flow diagram of a given process. Such diagrams provide an overview for managers and workers who need to understand 'the bigger picture' of what is going on. Further, this diagram can be used for identifying the unnecessary steps in a flow, thereby reducing waste. In the grid diagram in Fig. 1, the work processes are the operational subprocesses of the individual SCM processes. However, to fully exploit the understanding of work processes as a management tool, the organisational **behavioural processes** 'underneath' and embedded in the work processes must also be taken into account. Behavioural processes encompass, for example, how goals are set, how they are communicated and accomplished, how the organisation and employees learn and how members in the organisation relate to each other. Garvin (1998) particularly points to decision-making, communication and learning processes as important behavioural processes. The strategic SCM subprocesses may be understood as behavioural processes.

Finally, the overall and encompassing processes in Garvin's (1998) model are **change processes**, where the big question as to how change emerges and develops over time should be addressed: Is change going to be planned by top management, or does change emerge because of self-organising organisational entities? In their outline of change philosophies, Graetz and Smith (2010) identify a range of change philosophies where—in addition to the two just mentioned—change can also be induced by institutional pressures, competing agendas in the organisation and social-psychological factors. Here, we will primarily look at the rational and planned approach to change as opposed to the unplanned, emergent approach because these two philosophies fit this discussion best.

When change is *planned,* for example, because of IT disruptions, management will induce change by choosing and applying a concrete change model that incorporates work and behavioural processes. However, because IT implementation requires a high level of competency, often existing beyond management (Pleuger et al., 2019), change may *emerge* because of specialist employees rather than managers.

No matter the approach to change, to change work and behavioural processes, new skills are required (Greer & Ford, 2009). New skills may be obtained by acquisition (recruitment), but for an organisational transformation, this may not be enough. Individuals and organisations need to learn. Therefore, the next section will dig deeper into learning and the role of leadership as a behavioural process.

3.1 Learning and Leadership

Learning occurs at the organisational and individual levels within or independently of the workplace. Flöhtmann et al.'s (2018) study on SCM competencies finds that organisational and individual competencies have an equal impact on company performance.

The highest level of individual competency is, according to Flyvbjerg (2001) using learning theory, *expertise* where problems, solutions and actions are understood intuitively and synchronically. Along these lines, Derwik (2020) shows how supply chain professionals learn at work, indicating that junior and senior professionals do not use the same learning mechanisms. Juniors use *extra-occupational transfer of knowledge* such as formal education, *observation and copying*, as well as *practice and repetition*, to a much higher degree than senior professionals, whom we might characterise as experts.

Despite the point of departure of an organisational approach to learning, Derwik (2020) outlines a list of individual, professional learning mechanisms; these are categorised into three main types: (a) *interactional learning*, where learning takes place in collaboration with others; (b) *actional learning*, where learning takes place outside of oneself and singlehandedly, such as perspective switching and formal training; and (c) *cognitive learning*, where learning takes place inside oneself and contains submechanisms such as reflection and the unconscious absorption of knowledge. Understanding these learning mechanisms and deciding when to use them is of the utmost importance when designing an organisational learning strategy that is a fit for transformation. This typology can furthermore contribute to an explanation of Flöhtmann et al.'s (2018) finding that corporate training programmes are not as efficient a learning mechanism as learning through and with the organisation, where learning is situational and collaborative.

Derwik (2020) further points to the institutional levels in organisations where learning takes place, namely, in activities, in processes such as performance evaluation, in structure and in the organisational culture where feedback can be given in a psychologically safe environment where there is also room for reflection. Argyris (1977), however, outlines organisational learning theory based on systemic feedback mechanisms in single and double loops that, to a certain extent, are mechanistic.

Single-loop learning is reacting to the feedback of, for example, a technical flaw. The learners have to learn how to make this correction, but a technical solution exists and can be applied without further consideration. Work processes may be corrected by single-loop learning. Double-loop learning, on the other hand, is for problems that need deeper questioning of taken-for-granted assumptions and norms of problem solution. This may require confrontations between organisational actors, but the reward may be new ideas, innovations and processes. In most—if not all—cases, digitalisation will require double-loop learning because the new technologies question existing processes in an organisation. Further, as Pleuger et al. (2019, p. 5) claim, digitisation has increased the number of 'ill-defined problems with no universal solutions'. Therefore, the digitalisation of the various SCM processes, as depicted in Fig. 1, will require double-loop learning by questioning behavioural processes such as communication and decision-making. Expertise is not a necessary precondition for double-loop learning, and maybe, it can even be prohibitive because it is difficult to ask the difficult questions that are needed to change an organisation. However, proficiency in the contextual application of basic and rule-based skills is what makes an individual competent.

According to Derwik (2020), feedback is an interactional learning mechanism. Normally, feedback is thought of as interaction between people, but interestingly, Ransbotham et al. (2020) also point to an AI system as a device for this mechanism. The AI algorithm can 'learn' by itself through feedback loops once it has been set up by humans. However, humans can also 'teach' the AI system through interventions, and the AI can 'teach' humans by its feedback. Such teaching and learning may very well require organisational changes. This further points to the relevance of double-loop learning.

Derwik's institutional approach to learning contrasts Argyris' learning theory, despite the fact that double-loop learning requires positive institutional norms in connection to feedback (Argyris, 2004). However, because both Argyris' learning theory and the systems approach in general are well known in both management theory and practice (Nilsson & Gammelgaard, 2012), our focus is Argyris' systemic learning theory. Noteworthy is that both single- and double-loop learning are thought of as corrections to problems, though to different extents. In this chapter, we discuss transformations that arise because of new, disruptive technologies that are not self-imposed problems needing correction; therefore, organisational responses may be well accepted. Nevertheless, organisations will also need to ask themselves critical questions about how to abandon previous obsolete processes. This will most likely create prohibitive reactions in parts of the organisation because of fear of the transformation process' outcomes. Consequently, we still see double-loop learning as necessary in responding to disruptive new information technologies, and managers have an important role to play here.

Managers are the ultimate decision-makers. They do not need to make all decisions but will decide who has the right and responsibility to do so. They will need to set up learning processes, and particularly when double-loop learning is taking place, they have the responsibility for setting up learning processes and making sure that a positive learning culture where feedback of all kinds is welcome prevails (Argyris, 2004). However, particularly in double-loop learning, this also means that managers face 'dilemmas of power' (Argyris, 1977). Among these are that a manager should show strength and yet admit that change is needed; she/he should behave openly and yet is in control but should not be controlling. Further, the manager must also find a way to advocate a solution or viewpoint and still be open to confrontation about it. Important here is also that managers must help employees to manage fear while being fearful themselves about the upcoming transformations. Importantly, Pleuger et al. (2020, p. 3) point to 'facing the unknown' as an important element of digital transformation. Pleuger et al. (2020) recommend 'transformational and agile leadership' based on collaboration and a focus on people over tools as a solution to this high level of uncertainty.

In a discussion of IT implementation in the purchasing and supply organisation, Kauppi et al. (2013) also point to organisational aspects to be successful. Kauppi et al. (2013) draw on the theoretical concept of absorptive capacity, which means that for knowledge to be transferred from one organisation to another, there has to be a capacity to comprehend and assimilate this new knowledge. If not, it will not be applied, and the organisation will not be able to create value from it. In this context, this implies that organisations and individuals must gain competence in understanding and applying new technologies. This means that the difficult questions that double-loop learning requires must be addressed to further develop and maintain the necessary absorptive capacity. In other words, competence development is a necessity, and managers play a central role in this.

4 Competence Development

Learning at individual and organisational levels is a prerequisite for competence development, where SCM and procurement capabilities may be a source of sustainable competitiveness (Barney, 2012).

On the individual level, Gammelgaard and Larson (2001) differentiate between skills and competencies for supply chain management. Skills, such as operating IT software, can be learned independently of context and will require only single-loop learning. Compentency, on the other hand, are the ability to 'read' and react to contextual challenges beyond rational analysis and that do not following textbook cases and solutions (Flyvbjerg, 2001). A certain level of competencies will be necessary for double-loop learning to be able to question existing processes although it can also be prohibitive because the conscious acknowledgement of norms and values may have disappeared in the learning process towards proficiency.

On the organisational level, Van Weele (2005) finds six different competence levels (levels of maturity) in procurement organisations. The least mature level has a transactional orientation, and as in the following two levels, there is a decentralised, functional focus. At level four, the organisation integrates procurement tasks internally; at level five, external integration with suppliers takes place; and at the highest level of competence (most mature)—level six—value creation for customers and the value chain as a whole is the focus. It is suggested, through a diagram, that maturity rises with time (*x*-axis) and that effectiveness and efficiency (*y*-axis) increases with maturity level. Van Weele (2005) presents an analysis of the maturity of procurement in different industries in such a diagram, but the proposition of increasing maturity over time may also be understood normatively as an indication of a mechanistic future path of increasing competence development for any purchasing organisation.

In the same manner, Stevens (1989) talks about a stage model of the implementation of supply chain management. Along the same line, Bechtel and Jayaram (1997) identify schools of thought in SCM where the most basic school is termed the chain awareness school. Here, the various internal functions are conscious about being a part of a greater whole, but no linkages or integration activities are yet taking place. The most advanced school—or the most mature organisation—has integrated physical and information flows. As a future state, these authors see the integration of the same flows along the whole supply chain so that no single organisation stands out. Integration between all supply chain entities is complete. In both these models, the lowest level of coordination is found in the basic stages (schools), where tasks are performed and decisions are internally made by the various functions. Waste, here as buffer stocks, is piling up between these functions, and as functions and processes are integrated, waste disappears, and a higher level of SCM competency is obtained. As in the procurement maturity model, maturity is reached in the last stage (future state), where material and information flows are integrated within and among members of the supply chain.

All these maturity approaches indicate a predetermined and linear development path from an immature state to a mature one. However, how organisations go from one stage to the next is not so clear, except that time is a factor. Implicitly, the models indicate a life cycle model of change but without indications of the 'death' and 'rebirth' of the procurement organisations. One problem with these well-ordered and intuitive maturity models is that change from one stage to the next is not necessarily predetermined and sequential in real life. For example, Van Hoek et al. (2010) claim that change in supply chain management contexts is often a messy affair; this may be because maturing as a purchasing or SCM organisation is not predetermined but needs a 'human hand', for example, in the form of a so-called teleological change motor. Teleological change starts with management's dissatisfaction with a particular situation and then a search for solutions, followed by setting a new goal and at last implementing the solutions after the process starts all over again. Kotter's (2007) famous eight-step model is a prominent example of a teleological change model. Other 'change motors' are evolutionary selection because of external pressure and dialectics, where the 'change motor' is a type of conflict ending up in compromise (Van de Ven & Poole, 1995).

In their study of maturity models in procurement organisations, Andreasen and Gammelgaard (2018) find that development processes towards maturity were not planned and did not develop in linear ways and that the outcomes of the change processes were not predicted. For procurement managers, it was difficult, if not impossible, to see future goals because the procurement department is only one part of an organisation that must adapt or react to other parts with different goals. Therefore, supply and SCM organisations depend on and are a part of the political forces that are at play at any organisation. The present study further claims that competence development requires an understanding of change in four dimensions: (1) what *change motor* is at play (life cycle, plan, evolution or conflict), (2) what the *scale of change* is (unit, department or corporation), (3) what the *acceptability of change* is (what power bases for change are in place in the organisation) and (4) what the *substantive element of change* is (such as SCM or procurement work processes). In this discussion, the substantive elements that need change are SCM work processes. Figure 1 can help scale decisions regarding what IT tools and in what work processes should be used. Focusing on behavioural processes will help to get acceptance from the organisation, including the external supply chain. Without taking all these dimensions of change into consideration, developing the competencies of a procurement or SCM organisation looks simpler than it is. Consequently, the required changes may not happen, so the organisation will lose its competitiveness.

As indicated in the discussion above, new IT tools both require and create transformation beyond the predetermined life cycle model. An alternative 'change motor' worth considering is *evolution*; therefore, a look into complexity theory (Nilsson & Gammelgaard, 2012) is worthwhile. The main message of this theory is that the future—so also competence development—is not predetermined by either nature or management and, therefore, is not predictable. Organisational entities, such as employees, are self-organising through a few simple rules that enable them to adapt to changes in the environment. Along this line, Pleuger et al. (2019) suggest transformative and agile leadership with a great deal of empowerment of expert employees. Expert employees should be empowered through a few simple rules because managers cannot cover their expertise themselves; it will simply be too overwhelming. Furthermore, successful IT competence development allows organisations to focus more on the strategic development of work processes as routine work processes become automated. Management in the traditional sense is not so important anymore; transformational and agile leadership must take over, and instead of control, the focus must be on communication and the creation of meaning for organisational members (Pleuger, 2019). Both communication and sense-making are important behavioural processes well suited for complexity thinking (Nilsson & Gammelgaard, 2012).

Complexity theory, such as complex adaptive systems (CAS) theory, is about defining the rules for the individual that, together with other individuals, follow the same simple rules that make up a system (Burnes, 2004). However, systems can be observed at different levels because business units can be perceived as a system, as can organisations, supply chains and so forth. However, for all system levels, once these simple rules are defined and decided on, the organisation does not need change to be planned from a central decision-making entity such as top management. Further, the changes that are needed may not be clearly visible to neither employees nor strategic managers. This is because the organisation and competitive 'landscape' is 'rugged', meaning that when standing between mountain peaks (goals for competence development), it is not possible to see the magnitude of the other peaks and that some peaks may not be visible at all. Therefore, members of the organisation need to self-organise, and in doing so, the organisation will adapt to changes in the environment, such as institutional or competitive pressures. Also important is that the system needs to work at the so-called edge of chaos to work creatively. Too much stability, on the one hand, is 'death' because the system is not challenged and, hence, stands still while competitors move on. On the other hand, too much complexity is 'death' because the system gets lost in complexity (Nilsson & Gammelgaard, 2012).

However, management is still needed for setting up the frames for the organisation's learning and competence development—or in complexity management vocabulary—setting up the few and simple rooms for navigation. Here, double-loop learning processes fit in where agile teams will discuss existing work processes and how they may be improved by new technologies to transform the procurement and SCM organisation in the best possible way. Working for the team will be one simple rule in this complex organisation, and staying alert in one's professional communities could be another. Here, the manager must be aware of the blind side of expertise that may prohibit expert employees from asking critical questions about the new technologies. Further, it is management's role to make sure that there is a steady state of 'edge of chaos' through handling not only the paradoxes of management (Argyris, 1977) but also those of certainty and uncertainty and the tensions between large- and small-scale changes, slow–fast changes and internal–external stimuli (Graetz & Smith, 2010). Complexity thinking further sees paradoxes as natural when taking a human systems' perspective towards change. Conflicts, power, love, novelty and so forth are a part of everyday life (Nilsson & Gammelgaard, 2012), and it is a manager's job to balance these paradoxes.

For developing competencies, procurement and SCM leaders may still use the maturity models as inspiration but with caution when outlining the path for competence development. There will still be a need for developing the procurement of SCM-specific skills, even though some may be acquired, but leadership and collaborative competencies will be more important in future transformation processes. More employees must take on leadership roles, although not necessarily formally, and all must be able to collaborate despite conflicts, power, love and other human interaction traits. The formal leaders, on the other hand, must be able to handle the organisational paradoxes and, at the same time, plan learning processes and changes for the organisations to adapt to competition. Where the teams may agree on substantive elements for change and scale, it will still also be the formal leader's task to secure the acceptance of changes in the organisation and, sometimes, in the supply chain.

5 Summary

In sum, we recommend competence development emerging from new and disruptive technologies to start in the matrix in Fig. 1, where there is a list of technologies that may be paired with SCM processes. A good start will be to map existing *work* *processes* (SCM operational subprocesses) and then discuss each work process from each of the IT systems and value-creating potential in that. Maybe, the company already has applied one or more of the IT systems to one or more of the processes, and these can then be plotted into the matrix.

Hereafter, potential future paths can be discussed in double-loop learning sessions that go beyond the operational SCM processes and that discuss the strategic SCM subprocesses. These sessions must be based on transformational leadership, encompassing a positive learning culture that welcomes feedback. From here, the learning paths of individual employees may be discussed in agile teams and with individuals together with managers to make members of the organisation equipped for transformational competence development. Decisions on such *behavioural processes* are pivotal to the success of the transformation.

The discussion of *change processes*—the essence of competence development—is largely taking place in connection to the discussion of the so-called maturity models. In such models, competencies grow as time goes by, and there are marked lines between the stages in such competence development processes. Instead, we suggest that competence development in procurement and SCM organisations are complex processes that go far beyond the relatively simple, two-dimensional maturity models.

Maturity models in competence development may, though, be useful for understanding one's own development over time. However, it is important not to take maturity development as a given and to depend only on time. There must be a helping 'human hand' to plan and organise change processes, but from there, the competent members of the organisation must be set free to learn from and adapt to internal and external pressures to secure survival in the longer run in an evolutionary selection process. Furthermore, the choices of what to change (Fig. 1), to what scale and how to get acceptance in the organisations are other important dimensions of the change process that do not 'just happen' with time. Readiness for tackling tensions, power dilemmas and even paradoxes in the competence development processes is essential for transformational and agile leadership and is necessary for the IT-induced transformation of procurement and/or SCM organisations.

To conclude, we suggest that SCM competence development depends on the choice of which operational SCM subprocesses—the work processes—should be transformed by which information technology and to what extent. The success of this transformation will, however, depend on decisions on learning and leadership processes, among them the strategic SCM subprocesses. Finally, we suggest that changes in one part of the model in Fig. 2 will create a need for changes in other parts.

The 'sad' news is that competence development emerging from the new transformational IT systems is not as simple as indicated in the maturity models. The good news, however, is that using the models presented here and going through the steps may increase competitiveness far beyond cost savings. Drawing on Barney's (2012) resource-based theory—the so-called VRIN framework—unique value is created when resources are valuable, rare, inimitable and nonsubstitutable. Taking work processes, behavioural and change processes in competence development seriously

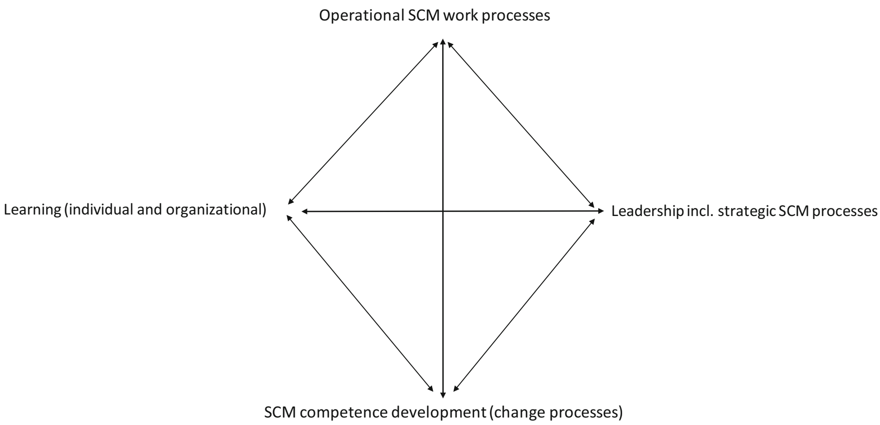

Fig. 2 Competence development: a transformational model (adapted from Garvin (1998))

will enhance the likelihood of creating valuable, rare, inimitable and non-substitutional resources and, therefore, a stronger position in the market that has equal access to the same technologies.

Management Perspective on Competence Development in Procurement Has Become Vital in Maersk and Ørsted

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A.P. Moller—Maersk and Ørsted are two of the largest companies in Denmark. In keeping costs under control, along with creating value for the company as a whole, the two companies have engaged in competence development. This development is fuelled by the new digital technologies that require new ways of organising procurement in many ways but also that require a greater emphasis on behavioural skills. Below, the reader is introduced to these two companies' approaches to competence development in procurement.

Flipping the Pyramid in Maersk: Automation Makes Procurement Strategic

In Maersk, we are working to elevate the procurement function to more closely support the strategic ambitions of our company. To do this, the procurement function must move away from transactional, manual tasks and instead spend more time focusing on strategic activities. The below model represents our vision for the future of Maersk Procurement.

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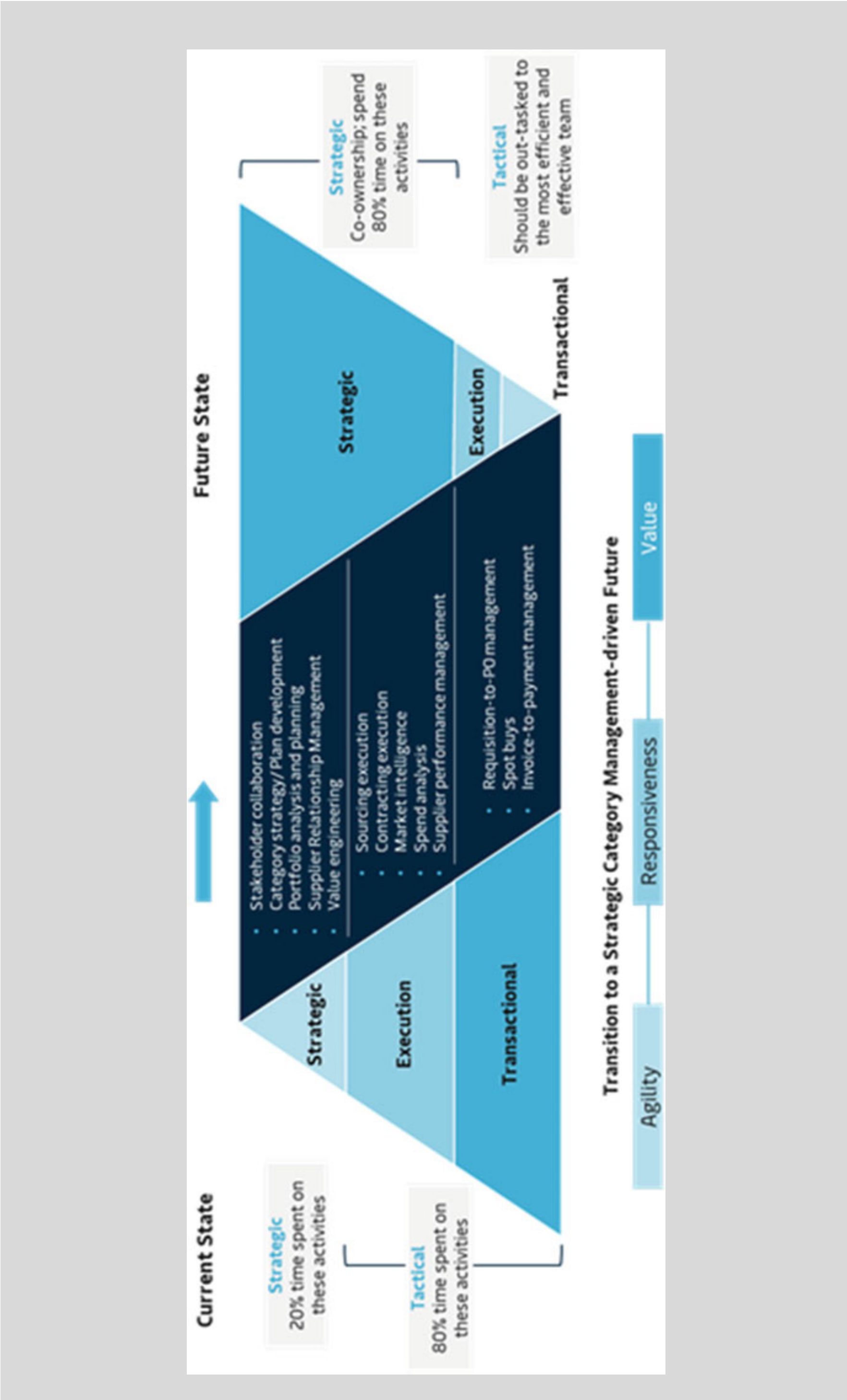

Current State
Future State
Strategic
20% time spent on these activities
Tactical
80% time spent on these activities
Strategic
Co-ownership; spend 80% time on these activities
Tactical
Should be out-tasked to the most efficient and effective team
Strategic
Execution
Transactional
Stakeholder collaboration
Category strategy/ Plan development
Portfolio analysis and planning
Supplier Relationship Management
Value engineering
Sourcing execution
Contracting execution
Market intelligence
Spend analysis
Supplier performance management
Requisition-to-PO management
Spot buys
Invoice-to-payment management
Strategic
Execution
Transactional
Transition to a Strategic Category Management-driven Future
Agility
Responsiveness
Value

(continued)

To 'flip the pyramid', we must automate most transactional and executional tasks to allow procurement colleagues to move toward strategic focus areas such as supplier relationship management/supplier-enabled innovation, business partnering (stakeholder collaboration) and category strategy, among others.

To move forward on this journey, we have invested heavily in digital technologies and capabilities in Maersk Procurement. We have been aggressive in pursuing new technologies, and in recent years, we have found that AI/robotics technology is the most effective way to reduce transactional and executional tasks.

Initially, it was important to train procurement colleagues in digital procurement tools, for example, e-Auctions software, for them to become familiar with technology interfaces and identify opportunities for AI processes. As we move more work into our AI workforce, we will continue to upskill procurement colleagues to interact with—and even to manage—their robotic colleagues.

Ørsted Focuses on Procurement Competencies

Any company needs to be aware of and react to the business environment that it operates in. The business environment—defined by the industry, the position in the supply chain, market position and so forth—has a profound impact on the business strategy. The business strategy will, in turn, define the strategy and targets for procurement.

Under the given strategic targets and delivery expectations, procurement must evaluate whether it can deliver. This ability depends on the maturity of the procurement function and its capabilities.

A department's capability is that department's ability to fulfil its assignments. This includes a balance between processes, systems and people. A change in any of these three areas will have to be reflected in the other two.

Competencies are the evaluation of the abilities employees have. Therefore, their competencies have a direct impact on the company's ability to deliver its strategic targets.

(continued)

How We Identify Competencies

Identifying relevant competencies is a pivotal part of ensuring procurement's ability to deliver. Over time, Ørsted has defined a stringent process to ensure that we have the right competencies and that these are at the right levels. In this process, we have to balance current and future needs. Competencies take time to develop; therefore, ensuring early awareness of coming competency requirements will be a competitive advantage for the company.

At Ørsted, our approach is a yearly process. We ascertain what skills are required to deliver on the immediate targets. Further, we have a constant eye on the business environment to try to spot upcoming opportunities and threats. In essence, we look outward at competitors, suppliers and academia, as well as inward at our changes in strategy, delivery models, systems and processes to see if we can identify future skill requirements. Regarding our known competencies, we run a yearly gap analysis to ensure that we have the right competencies at the right level.

How Do We Work on Competency Development?

To answer this question, we have to realise that there are two types of competencies: competencies we can develop and train and those that people intrinsically have. The latter kind are typically referred to as behavioural skills and are harder to train; therefore, we focus on hiring people who have these skills.

At Ørsted, we focus on developing not only training, but cultural changes. Hence, we do not just offer, for example, negotiation training, but we aim to change the culture around negotiation as a topic. We have our Procurement Academy, but to ensure that the training is applied and used, we include management and the organisation when developing a skill.

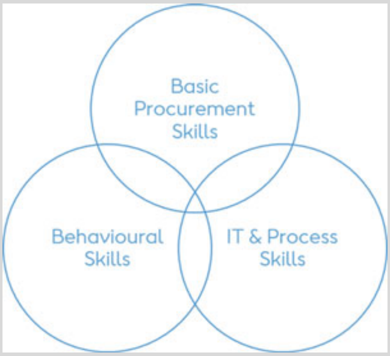
What Competencies Are We Focusing on Now?

When looking at the competencies in focus right now (2021), we at Ørsted can identify three major skill areas:

– Basic procurement competencies—It is important that people in procurement are competent in the tools of the trade. They should have the right level of understanding of the business; understand the legal requirements involved in procurement; perform the right analyses to develop strategic sourcing; and be sufficiently able to run negotiations.
– Behavioural or interpersonal skills—Over the past few years, Ørsted has realised that for a procurement function to be the most efficient, it needs to have strong 'soft skills'. Being innovative; working together with other people; working with suppliers; being willing to take responsibility and set a direction; being able to communicate the direction; and convincing other parties of that direction are all in focus here. Working on supplier relationship management requires many of these skills.

(continued)

– Digitization and digitalization—Finally, we focus on understanding our systems and process landscape. Ørsted is developing in the area of digitisation and digitalisation (i.e. implementation of digital solutions), so here, the focus is on adoption and change management. In the future, looking at utilising the new opportunities offered by these developments, including AI and robotics, will have a profound impact on the business and, therefore, will become a central part of our capability building.



Future Competencies in Focus

As indicated above, Ørsted and Maersk continuously monitor the need for competencies, especially future competencies, because competencies take time to develop or attain.

Currently, Ørsted and Maersk are looking into six specific competency areas they believe will be relevant in the immediate future:

1. **Digital procurement**—Because this area promises new efficient and effective opportunities, Ørsted and Maersk will focus here. Not only the possibilities promised but the ability to adapt and utilise new technologies will be prioritised. This focus will help ensure that procurement colleagues can focus on more strategic activities and deliver more value to the business.
2. **Leadership**—To harvest the value offered by procurement, procurement must promote said value. To do this, procurement must be proactive and able to set the proper direction. Further, procurement must be able to communicate and convince others about this proposed value. This requires proactive leadership skills for all employees. In Maersk, it is important that we continue to develop leadership to maintain a strong procurement organisation. We truly believe that we are only as good as our people and that engagement is paramount to retain and develop our function.

(continued)

Leadership is key on the journey toward the procurement organisation of the future.

3. **Relationship management**—In an interconnected world and with more and more opportunities for optimising value beyond the boundaries of the individual company, Ørsted and Maersk will focus on relationship management. This will be the focus both internally in the company and externally, primarily with suppliers. Win–win opportunities and a strategic approach to suppliers will be explored further.
4. **Innovation**—Ørsted's ability to innovate within the field of procurement will help Ørsted remain at the forefront of our industry. Concepts such as co-creation, supplier-enabled innovation and supply chain development will become more commonplace going forward.
5. **Customer and product focus**—In Maersk, the customer should be central to everything we do. We must be focused on customer needs to create products that provide the most value for the organisation and for our customers. The procurement organisation must work to ensure that seamless customer solutions and related products are available.
6. **Self-management**—With COVID-19 changing the way we all work, the focus will be on how we best handle these new ways of working. Ørsted will make working from home a permanent part of how we organise ourselves going forward. This and other new opportunities will require that the individual be better at organising work him- or herself, and we have to be aware of how this new approach affects people and the collaboration required to ensure the best results. We want to avoid new types of stress and help people change to a—hopefully—more efficient and enjoyable work life.

Therefore, we welcome a book on global supply chain management skills and support the ideas of looking into work, behavioural and change processes, when developing and implementing the procurement skills necessary to stay competitive in the future. The development of procurement skills and adding value to the company as a whole is clearly an organisational endeavour that requires dedication and time.

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Startups in the Logistics Sector: Value Propositions and Potential Impact

Stephan M. Wagner and Stefan Kurpjuweit

1 Introduction

With acceleration of digitalization in all areas of life, consumers are used to easily book flights or hotel rooms or to just compare prices on almost every product online. When it comes to cargo, however, it regularly takes several days for companies to book a shipment from Hamburg to Shanghai—without having full transparency regarding costs. Internet-accustomed shippers are thus increasingly urging their logistics service providers (LSPs) to adapt their service offering to the digital age. Incumbent LSPs apparently struggle to satisfy these changing customer needs. Especially, LSPs' general lack of innovativeness (Busse & Wallenburg, 2014; Wagner, 2008) is potentially hampering their ability to develop the necessary capabilities to accelerate the digital transformation of their businesses. In contrast, startups are recognized for being a source of innovation and a driver of technological change (Song & Di Benedetto, 2008).

This situation is highly attractive for new entrants. Consider for example the Berlin-based digital freight forwarder *Forto* (previously *FreightHub)*. Its value proposition is simple: *Forto* offers real-time freight quotations and booking to shippers and carriers, making cargo shipments as easy as booking apartments via *Airbnb*. Founded in 2016, *Forto* recently raised another USD 50 million to a total of USD 103 million (Butcher, 2020), which is a comparatively large amount for a young European venture. But *Forto* is only the tip of the iceberg. CB Insights (2016) reports that global venture capital investments in logistics startups multiplied by 16 from only USD 0.3 billion in 2012 to over USD 5 billion in 2016. Saller and

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Klühr (2021) observe that venture capital funding into logistics startups grew tenfold, from USD 1.6 billion in 2014 to over USD 12 billion in the first three quarters of 2019. In sum, we see a considerable growth in funding and, hence, strong interest in logistics startups.

Established logistics players have started reacting to this development. The venture capital arm of UPS, *UPS Ventures*, has been investing in logistics startups for a long time (but also divested), for example, in crowdsourced delivery service startup *Deliv* (founded 2012) or autonomous driving trucking technology startup *TuSimple* (founded 2015) (Carey, 2019). Similarly, in 2019, *Kuehne + Nagel* partnered with Singapore's *Temasek Holdings* to launch *Reefknot Investments*, a USD 50 million venture capital fund for logistics startups (Pillai, 2019).

The scholarly literature has just begun to investigate the phenomenon "logistics startups" and to expand the body of knowledge on the role of startups in the logistics sector (Göpfert & Seeßle, 2019; Wagner, 2021). The aim of this chapter is to contribute to the scholarly debate and to explore the rise and potential impact of startup firms in the logistics sector. Accordingly, we raise three research questions: (1) How can emerging logistics startups be categorized, (2) how do logistics startups affect incumbent players in the logistics sector, and (3) what are implications for logistics startups' vale propositions?

The structure of the chapter is as follows. In Sect. 2 we discuss some relevant background on logistics corporates, startups, and value propositions. Section 3 develops and discusses a categorization framework for logistics startups and startups' value propositions. Section 4 outlines how logistics startup firms might affect incumbent logistics companies. Section 5 closes with a summary and concluding considerations for LSPs and startups and a view on the skills needed by logistics startups and corporates.

2 Background

2.1 LSPs and Innovation

The literature suggests that LSPs' competitiveness increasingly relies on their capability to embrace innovations for adding value to a shipper's value creation setup (Wagner & Sutter, 2012). In the logistics context, Flint et al. (2005, 114) define innovation as "any logistics related service from the basic to the complex that is seen as new and helpful to a particular focal audience. The audience could be internal where innovations improve operational efficiency or external where innovations better serve customers." Wagner (2008, 220–221) further adds that both "the development of a new logistics concept on the one hand and the adaption and implementation of an existing logistics concept on the other are part of a LSP's innovation activities."

The logistics industry scores lower in terms of innovation expenditures and innovation output, in comparison to other industries (Wagner, 2008). Wagner (2008, 219) notes that R&D expenditures, "if existing at all, [were] usually only marginal." He links this finding to the industry's role as a technology adopter and to its service-based nature. Furthermore, when investigating the innovation activities of 13 LSPs in Germany, Busse and Wallenburg (2014) could not find a single firm that had established a dedicated group of people responsible for innovation topics, not to mention a formal innovation department.

Since LSPs often lack necessary competencies to innovate internally, external relationships are considered to be suitable for acquiring knowledge and for compensating this lack of internal innovativeness. For example, Wagner's (2013) findings indicate that customers, suppliers, and competitors are valuable sources for improving service offerings of LSPs, while for developing new services, only partnerships with customers seem to be beneficial for LSPs. Another study shows that close relations to current customers are positively associated with internal process innovations and new service offerings for existing customers, while close relations to other service providers improve LSPs' propensity to introduce new services for new customers (Bellingkrodt & Wallenburg, 2013). In addition, the same authors stress the importance of deploying broad scanning approaches not only to tap into the knowledge of existing companies but also to identify new sources of innovation.

Logistics startups are a source of innovation for established LSPs. Due to the digital transformation of the logistics sector, new logistics startups constantly enter the market with innovative offerings. Established LSPs and shippers may tap the innovation potential of these startups (Mikl et al., 2020; Sucky & Asdecker, 2019).

2.2 Logistics Startups

To be considered as a startup (or new venture), studies apply different cut-off points regarding the maximum age. Prior studies allow for a maximum age in the range of 6 to 8 years (Kurpjuweit et al., 2021). In addition to their age, new ventures are typically demarked from established companies by several other characteristics. For example, new ventures differ from established firms by having less legitimacy in the marketplace (Singh et al., 1986) or fewer financial or human resources (Shepherd et al., 2000). They also lack routines for customer interaction, and they possess only rudimentary operational and management capabilities (Terjesen et al., 2011). Consequently, startups show a higher risk of defaulting (Aldrich & Ruef, 2006).

New ventures typically operate in a trial and error mode, experimenting with different ways of creating value and pivoting when their current business models turn out to be not suitable for seizing the expected opportunities (Ries, 2011). In combination with their organizational limitations, such behavior makes collaborations particularly difficult.

Despite these organizational handicaps, new ventures make fast decisions and communicate directly and informally, providing advantages in terms of flexibility and agility when compared to mature companies (Das & He, 2006). Their fast pace is particularly driven by the necessity to introduce new products quickly in order to generate cash flows to secure survival. Furthermore, aspiring growth is an underlying characteristic of most entrepreneurial firms (Zimmerman & Zeitz, 2002).

Essentially, new ventures pursue a strategy of sacrificing financial performance in the present and nearer future to increase sales and market share, aiming to grow (Covin et al., 1990).

Partnering successfully with new ventures requires special capabilities from established firms that allow them to leverage startups' unique resources (Zaremba et al., 2017). These partnering capabilities, however, are organizational capabilities that need to be learned over time, as they cannot be acquired externally. Consequently, LSPs and shippers need to build up the resources and capabilities to partner with or integrate logistics startups that offer value for the LSPs, the shippers, and their downstream customers or consumers.

The logistics startups we are interested in are not newly founded companies that simply replicate a conventional logistics business (e.g., starting a trucking business), but rather one that introduces an innovation for LSPs' themselves or to a subset of LSPs' customers. Reflecting this focus, we define a logistics startup as a new venture whose value creation process is closely linked to the logistical activities of LSPs.

Studies on 'logistics startups' or startups in the logistics industry are still scarce (Göpfert & Seeßle, 2019; Wagner, 2021). Notable exceptions exist in the general context of digital transformation in the logistics service industry (e.g., Cichosz et al., 2020; Sullivan, 2021; Sucky & Asdecker, 2019), and particularly on innovative solutions and the involvement of startups in last mile and crowd logistics or delivery (e.g., Carbone et al., 2017; Castillo et al., 2018; Frehe et al., 2017). One study studied logistics startups' use of agile methods and practices (e.g., Scrum, lean startup, refactoring, pair programming), the benefits of these methods and practices for the logistics startups, and the challenges they face applying them (Zielske & Held, 2021).

2.3 Value Propositions

Value propositions define how a firm's product and service offerings translate into benefits for the customer and why the customer should choose the firm's offering over a competitor's offering. Similarly, a (customer) value proposition "conveys what superior value targeted customers can expect from engaging with the firm" (Payne et al., 2017, p. 475). Value propositions—in conjunction with a firm's approach to value creation, value capture, and the structuring of the value network—are the key elements of a firm's business model (Velu, 2016; Teece, 2010). While defining the value proposition and the superior value customers can benefit from is already difficult for larger and established firms, it is even more challenging for startups.

Value propositions of logistics startups frequently circle around big data that supports LSPs or shippers to automate (batch) and improve efficiency (transaction) or new information services to improve decision-making, increase transparency, or reduce risk (digital data stream) (Pigni et al., 2016), where digital data streams offer the vastest potentials.

For startups it is recommended to create not only an "innovative offering value proposition" but also a "leveraging assistance value proposition" (Wouters et al., 2018). In the former, a logistics startup could expound the benefits for a LSP or shipper and additionally offer an extraordinary tailoring of a solution or grant exclusivity. The latter "conveys what support and resources the customer firm will provide to the startup to help it realize the innovative offering, and what the customer firm will get in return for providing the support and resources" (Wouters et al., 2018, 105–106). A logistics startup might require a pilot customer to refine and tailor the prototype solution (so that the customer gets more value from the solution) or simply win the first customer (leading to further customers and higher likelihood of success and survival, which is in the interest of the first customer) (Kurpjuweit & Wagner, 2020).

3 Categorizing Framework

3.1 Procedure

As an initial step to create knowledge on what logistics startups are and how they can be categorized, we conducted a qualitative content analysis. Qualitative content analysis is suitable for analyzing and identifying similarities and differences in the descriptive and latent content of the text. This method has not only been widely used in general management research (Scandura & Williams, 2000) but also in supply chain management (Montabon et al., 2007). Recently, Carbone et al. (2017) investigated the topic of crowd logistics by examining the content of the websites of different crowd logistics initiatives.

In order to identify suitable startups for our investigation, we used the startup database from the market research firm *CB Insights* (www.cbinsights.com), one of the largest international startup databases. We restricted our search to startups meeting the following four criteria: (1) firms from the logistics and supply chain category; (2) firms founded between 2012 and 2017; (3) firms based in Germany, Austria, or Switzerland; and (4) firms currently operating. This process resulted in a list of 54 ventures. For each startup, we then checked whether its main focus was on B2B. Startups that were clearly out of interest for LSPs and shippers were sorted out (e.g., *Minodes*, which offers a platform for in-store retail analytics). After this process, the list contained 43 startups. In order to identify additional logistics startups meeting our criteria, we screened practitioner publications on logistics startups, specialized startup websites (e.g., gruenderszene.de), and *Crunchbase*, which is another startup database. We found many startups to overlap with the startups we already identified via *CB Insights*. Nevertheless, we could add 32 additional logistics startups, resulting in a final sample of 74 logistics startups from Germany, Austria, and Switzerland.

For our content analysis, we used the websites of these startups as the main data source. Websites offer easy access to secondary data and their use has been validated by previous research (e.g., Carbone et al., 2017). All websites were downloaded to enable a systematic analysis. Following the rules of a conventional content analysis (Hsieh & Shannon, 2005), one researcher inductively coded all the data without any predefined coding structure. The coding process led to several categories that share common characteristics. A category describes the "what?" (Morse, 2008) and is used to describe variations in texts mainly on manifest content. Subsequently, we moved from the concrete to a more abstract level and grouped the subcategories into four broader main categories. To increase reliability, a second researcher screened all websites again and compared them with the codes. Disagreements were discussed and, if needed, startups were recategorized until full agreement was reached.

3.2 Findings

Our qualitative content analysis of 74 logistics startups' websites resulted in several subcategories, which we could aggregate into four main categories (Table 1). In the following, we will briefly describe them.

Intermediation Platforms Intermediation platforms enable the interaction of different logistics parties via a digital interface. The focus of these platforms lies in matching supply and demand of logistics activities. In the digital age, a platform serving an intermediary purpose between two (or more) user groups develops significant market power by profiting from network effects, i.e., the user value increases with the user base. The value proposition of logistics startups offering intermediation platforms frequently concerns the reduction of search and transaction costs and an increase in business through a network and scale effect.

Software Providers The core capabilities of startups from this category lie in software development and the management and analysis of data. For startups, whose product also has a hardware component (e.g., tracking and tracing), the principal innovation is mainly the software and only partly the hardware, given that hardware (e.g., sensors) is often externally purchased. Nevertheless, as software startups can easily extend their service offerings or pivot their business models, the borders between the subcategories might be slightly blurred. For example, tracking and tracing functionality is often an enabler for additional services such as fleet management. The value proposition of software provider logistics startups frequently concerns customer benefits through the digital data stream, decision support, or visibility.

Hardware Technologies This category is about tangible technologies (i.e., hardware), which are applicable in a logistics context. Startups from this category typically have filed patents on a tangible innovation, and in contrast to the software category, hardware logistics startups use software, if at all, only to support the functionality of their tangible product. Their value propositions frequently concern process innovations and improvement of process efficiency.

Table 1 Categorizing framework for logistics startups (*, number of identified startups)

Category	Subcategory	Representative quotes	Startup examples
Intermediation platforms	Digital freight forwarding (7*)	"The digital freight forwarder." (Forto)	Forto; InstaFreight; Cargonexx
	Freight marketplaces (5)	"The price comparison tool for sea freight." (Freightfinders)	Cargo-Bee; Freightfinders; Pickwings
	Storage and warehousing marketplaces (3)	"You can find your storage space and fulfilment capacity online and book flexibly without any extra effort." (DepotCity)	Log-hub; StoreMe; DepotCity
	Other intermediation platforms (8)	"A bulletin board for logistics services." (CargoHit)	CargoHit; Demogate; xChange
Software providers	Tracking and tracing (10)	"The sensors record environmental conditions that goods are subject to while in transit." (Modum)	CargoSteps; Modum; Nexiot
	Fleet management and route optimization (7)	"Flutaro makes route planning easy." (Flutaro)	Flutaro; FleetLink; Bestmile
	Big data analytics (3)	"Using a big data approach, we analyze the routes travelled by our participants in order to be able to offer them the perfect match." (AlgoTruck)	AlgoTruck; GenLots; riskmethods
Hardware technologies	External logistics hardware (4)	"Safest pharma containers. Worldwide." (SkyCell)	Twortybox; SkyCell; Wingcopter
	Intralogistics hardware (7)	"Magazino develops and builds perception-controlled, mobile robots for intralogistics." (Magazino)	Magazino; ProGlove; Picavi
CEP services	CEP delivery (9)	"Ship your products with byrd and save time & money." (byrd)	Liefery; byrd; Packator
	CEP infrastructure (7)	"Staff can legitimately receive private packages at their place of work." (Packadoo)	emmasbox; Packadoo; ParcelLock
	API integration (4)	"Vendors can use an intuitive and easily integrated standard interface (RESTful API) to connect their store or enterprise resource planning (ERP) system directly to all major package shipping providers." (shipcloud)	shipcloud; Seven Senders; Sendcloud

CEP Services This category includes all business models, which directly relate to the activities of incumbent CEP service providers, such as the delivery of goods, fulfilment services, the necessary infrastructure, or the interconnection of shipping parties and carriers for data exchange. The last mile is not only the most expensive part of the delivery process but also has gained attractiveness as demand for last mile services has been continuously increasing. This environment creates many opportunities for startups, which is also indicated by a large number of startups we identified. In this category, the value propositions of logistics startups vary and might range from efficiency improvements and transparency to enhanced customer experience and environmental sustainability.

Comparing previously discussed classifications for logistics startups with our categorizing framework shows a strong consensus. Building on and expanding the categories (1) infrastructure, (2) CEP services, (3) data, and (4) technologies offered by Holdorf et al. (2015), Göpfert and Seeßle (2019) identified—based on the startups' *business areas*—six categories, namely, startups offering (1) infrastructure, (2) warehousing, (3) technologies, (4) CEP services, (5) logistics software, and (6) online platforms. Klyukanova (2021) aims to enhance the understanding of logistics and supply chain startups from a *business model perspective* and classifies startups based on the type of service offering: (1) last mile delivery services, (2) e-commerce logistics, (3) rate comparison and marketplaces, (4) software as a service and big data, (5) warehousing, (6) digital forwarding, (7) autonomous driving vehicles, and (8) transport management systems and blockchain.

4 Logistics Startups' Potential Impact on LSPs

4.1 Procedure

To shed light on how logistics startups affect incumbent players in the logistics sector, we follow an inductive, multiple-case study design. To gain a comprehensive understanding of logistics startups' potential impact on established logistics companies, we selected startups as well as established firms. For the startups, we used the database built for our categorization framework, as such that we contacted equal numbers of firms from each of the four identified categories. Regarding the established logistics firms, we only selected firms which had made first experiences with logistics startups, as we wanted to interview managers who were familiar with the topic and who could refer to real examples. Our final sample consists of 19 firms—11 logistics startups and 8 established logistics companies, whereby not only the logistics startups belong to different categories. We also tried to increase the heterogeneity of our LSP sample by selecting LSPs with different business models. Therefore, we selected four freight carriers focusing on different transport modes (road, rail, sea, air), three forwarders and 3PLs, and one courier, express, and parcel (CEP) company. Through this sampling strategy, we could cover all major established players in the logistics sector. The LSPs representing the three business models and the startups from the four different categories resulted in seven "cases." Tables 2 and 3 summarize their characteristics.

Table 2 Overview of startup case firms

Case	Category	Firm	Subcategory	Founding year	Number of employees	Informants
1	Intermediation platforms	IP-1	Digital freight forwarder (sea)	2016	30	Regional lead
		IP-2	Digital freight forwarder (land)	2016	20	CMO
		IP-3	Freight marketplace	2016	4	Managing director
		IP-4	Other intermediation platforms	2015	15	Managing director
2	Software providers	ST-1	Tracking and tracing	2015	29	CFO
		ST-2	Tracking and tracing	2012	100	Sales director
3	Hardware technologies	HT-1	External logistics	2013	< 5	CEO
		HT-2	Intralogistics	2014	30	Sales engineer
4	CEP services	CEP-1	CEP infrastructure	2013	12	Sales director
		CEP-2	API integration	2013	13	CFO
		CEP-3	API integration	2015	50	Managing director

Table 3 Overview of established case firms

Case	Category	Firm	Business focus	Revenues [EUR]	Employees	Informants
5	Freight carrier	FC-1	Sea transport	5–10bn	10,000–20,000	Global director container logistics
		FC-2	Air transport	1–5bn	500–1,000	Head of cargo business development
		FC-3	Rail transport	1–5bn	20,000–50,000	Innovation manager
		FC-4	Road transport	0.1–1bn	500–1,000	Division manager forwarding
6	3PL and forwarding	3PL-1	General	>10bn	>50,000	(1) Senior VP innovation (2) CEO (largest shareholder)
		3PL-2	General	>10bn	>50,000	Global innovation manager
		3PL-3	General	5–10bn	10,000–20,000	Head of digital innovation
7	CEP service provider	CEP	General	5–10bn	20,000–50,000	Global innovation manager

Data Collection The main source of data is 20 interviews with representatives from logistics startups and established logistics companies. To account for the different perspectives, we used different semi-structured interview instruments for startups and for established firms. The interviews lasted between 35 and 86 minutes (62 minutes on average). For 19 out of 20 interviews, a recording was permitted by the interviewees. These 19 interviews created a rich database of 239 pages of transcript (single-spaced, 11 pt). We guaranteed anonymity to all informants to promote openness and a sufficient level of detail. We complemented our interview data with archival data from internal and external sources. Besides the stored startup websites used for the development of our categorizing framework, we always asked our informants for internal reports and presentations. Moreover, we collected press releases, the most recent annual report(s), blog posts, and newspaper articles. For the startups, all of the published data were of interest, as they helped us to better understand their business models and their potential impact. Conversely, the publicly available data about established LSPs had to be related to their startup activities. Overall, we collected 422 pages of archived data (approx. 21 pages per firm without annual reports), which served as a second data source for our analysis.

Data Analysis Data collection and analysis overlapped in an iterative manner to adapt the procedure and to better cater emergent themes (Eisenhardt, 1989). The data analysis is divided into within-case analyses and a traversal analysis of all cases to balance unique and generalized patterns (Eisenhardt, 1989). For each of the seven cases, we developed a comprehensive case description. For the cross-case analysis, we used the software MAXQDA. To thoroughly investigate the question of “how” and “why” B2B logistics startups might impact incumbents, a balanced coding scheme was developed. The coding structure was inductively developed during the data collection process, catering to the incremental approach of case study research.

4.2 Findings

The findings from our multiple-case study suggest that the rise of logistics startups is associated with several positive and negative effects on established LSPs. In order to provide a comprehensive picture, we summarize the potential effects for freight carrying, 3PL, and forwarding, as well as for CEP service providers separately in Table 4.

The results of our multiple-case study reveal that the four startup categories affect the three major logistics players differently. For instance, while startups focusing on the delivery and infrastructure of parcels exclusively affect established CEP service providers, other logistics startup types, especially intermediation platforms, seem to have a much wider impact in the logistics sector. Intermediation platforms aim to create full price transparency, which may be seen as a significant threat for the business models of many freight carriers, 3PLs, forwarders, and CEP service providers, as price discrimination among their customers is one of their major profit levers. Indeed, full price transparency could erode the already low margins in some

Table 4 Logistics startups' potential impact on established LSPs ("+," positive effect; "–," negative effect)

	Freight carrier	3PL and forwarder	CEP service provider
Intermediation platforms	+ Increased capacity usage of transport assets. + Improved customer experience (facilitation of post-booking process). + Reduction of manual work through automation of order processing. + Acquisition of new customers (without 3PLs). + Decrease dependence from 3PLs. – Full price transparency.	+ Short term availability and immediate booking of additional capacities. + Reduction of manual work through automation of order processing. – Full price transparency. – Loss of market share. – Pure brokers become redundant. – Weaker position in carrier relationship.	+ Booking of additional capacities (e.g., truck carriers for tours to and from hubs). + Offer fulfilment services via intermediation platforms. – Full price transparency.
Software providers	+ Improved operational efficiency (e.g., improved capacity usage). + Offer additional services to customers (e.g., tracking and tracing). + Direct access to data (not through 3PLs).	+ Improved operational efficiency (e.g., lower safety stocks). + Offer additional services to customers (e.g., integrated risk management).	+ Improved operational efficiency (e.g., routing). + Offer additional services to customers (e.g., tracking and tracing).
Hardware technologies	+ Improved operational efficiency (e.g., flexible transport assets).	+ Improved operational efficiency (e.g., faster picking).	+ Improved operational efficiency (e.g., faster picking).
CEP services	*No effects found*	*No effects found*	+ Improved integration of shippers and CEP carriers. + Higher transparency of carrier performance. + Improved customer service. – More competition. – Loss of market share.

segments of the logistics industry, but there might be even more far-reaching consequences. Freight carriers could become more independent from 3PLs and forwarders as they could offer capacities via digital platforms directly to shippers. Moreover, freight carriers could systematically try to engage with new customers, offer additional value-creating services (e.g., tracking and tracing) without the need to involve a third party into the collaboration, and gather direct feedback from these customers about their service offerings.

5 Summary and Concluding Thoughts

5.1 Summary

In this study, we offer fresh insights into the phenomenon of logistics startups. Based on an extensive content analysis of 74 logistics startup websites, we propose a systematic and comprehensive categorizing framework for logistics startups. We inductively developed 12 subcategories which we then grouped into 4 major logistics startup categories. The categorization contributes to a better understanding of how logistics startups create value and how they affect established LSPs.

The results of our multiple-case study reveal that logistics startup types affect the logistics sector differently. Specifically, forwarders and 3PLs seem to be the most severely affected companies in the market. They already lose market share to digital platforms. For some shipments, they could even become obsolete. Especially for smaller, standardized, and less complex shipments, intermediation platforms are already a viable alternative for many shippers. Therefore, intermediation platforms are perhaps a more attractive object of investigation for LSPs and for scholars than the related crowd logistics phenomenon (Carbone et al., 2017; Frehe et al., 2017), which is covered by the CEP service category that shows only very specific implications for a small fraction of the logistics sector.

Furthermore, our results suggest that startups not only affect logistics firms' established relationships and business models but that they can also be a viable source of innovation for LSPs. So far, the logistics literature has largely ignored the innovation potentials that startups offer. Instead, past studies concentrated on customers, suppliers, or other LSPs as innovation sources (Bellingkrodt & Wallenburg, 2013; Wagner, 2013). Especially software and hardware startups, however, are predominantly associated with positive effects on all three types of established LSPs. Through innovative tangible and intangible technologies, they primarily improve LSPs' operational efficiency or enable LSPs to create new value through offering new services to their customers.

5.2 Considerations for LSPs

To fully realize this innovation potential, LSPs need to partner effectively with these startups. This could become challenging due to their often limited experience in such asymmetric collaborations. Notably, all LSPs of our study acknowledged that they are in the early stages of their startup activities and that they are still experimenting with possible ways to collaborate effectively. Compared to previous studies, this means that LSPs show a substantially stronger propensity toward innovation activities. This is also reflected in the fact that all case firms have established dedicated innovation teams or even formal R&D departments, a substantial improvement compared to the findings of earlier studies (Busse & Wallenburg, 2014).

5.3 Considerations for Logistics Startups

For a logistics startup, it is decisive to assess how crowded the logistics market it aims to enter is already and how many more mature startups are in the market already. A crowded market implies that an entry would merely add another player in the game, and it will be hard to develop and communicate an extraordinary offering to LSPs or shippers. But the extraordinary offering is a prerequisite for the "innovative offering value proposition" (Wouters et al., 2018). For example, developing a novel business model for bicycle express delivery for business customers would require additional services to result in customer benefits over what is already on the market. Ordering and delivery marketplaces, tracking systems, and payment systems already exist. What else could create value for business customers? Furthermore, if the envisioned logistics space is only occupied by early-stage startups with bigger players staying out of it, the space might not be very promising.

Our interviews with the corporates, LSPs as well as carriers, and with the logistics startups reveal that the B2B context, which we have chosen for this study, requires substantial endurance from startups. Any value proposition needs to provide substantial benefits for a potential corporate customer. Furthermore, the sales and business development processes are much longer compared to logistics startups in the B2C/C2C context and progress through several stages, such as proof of concept, pilot project, site implementation, and rollout. Two to 3 years for the initial major customer are rather the rule than the exception. Requirements and rigidities of corporate customers, for example, concerning process stability, system interfaces, or data security, are highly demanding. Hence, crafting and implementing a value proposition for a logistics control tower at a corporate is disparately more challenging than a shared hauling and moving platform for consumers. But once the corporate decides to use and roll out the startup's B2B offering, the logistics startup can expect continuous revenues.

5.4 Skills of Logistics Startup Entrepreneurs vs. Logistics Corporates

The personalities, competencies, behaviors, and skills of startup entrepreneurs and the influence of these on startup success, survival, or growth have been widely studied (e.g., Bird, 2019) and are beyond the scope of this chapter. Lazear (2004, p. 208) claims that "entrepreneurs must be jacks-of-all-trades to some extent . . . need not be expert in any single skill . . . [but] sufficiently good at a wide variety to make sure that the business does not fail" while "those who work for others should be specialists." This seems to be different in the logistics sector, where the study of skills, competencies, and career development paths of supply chain employees and employees at logistics corporates shows that cross-functional knowledge and experience is a desired skill (Flöthmann & Hoberg, 2017). Hence, in the logistics sector, successful employees at corporates and successful startup entrepreneurs might both need to possess broader and generalist skills.

Given that the logistics sector is competitive—and frequently price-driven—we know from our interviews and our own experience that firms in the logistics sector are often quite operational and pragmatic, be it in winning a business from a customer or developing a service or solution. New logistics services are often developed in partnership with the customer or shipper (Wagner & Sutter, 2012). This again is very similar to the situation of logistics startups that approach potential customers with a "half-baked" solution, a prototype at best, and need a potential customer who is willing to engage in a pilot and offer a platform for customization and final development of a hardware, software, or solution.

Two skills or traits are different and might prevent that logistics startups and logistics corporates get on the same page. First, as outlined in the introduction, logistics startups obtain funding to venture into fields where it is unclear whether and when it is possible to earn money. Logistics corporates—even the ones that are run or owned by seasoned entrepreneurs—seem less willing to invest if the return is not guaranteed. Only a few began dedicating "strategic budgets" for technological developments or digitalization. Second, risk is inherent in any venture activity and startups take risk. Logistics corporates seem less willing to take risk. They have always and often successfully dealt with exogenous risks—from freight rate volatilities to financial crises—but are less willing to enter into "risky" ventures.

In short, the skills and traits of logistics startup entrepreneurs and logistics corporates have a number of communalities, and for a more intensive collaboration between the two, the willingness to strategically invest and take risks should be revisited.

Management Perspective on Decoding the Logistics Startup Skill Set

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Over the past 5 years, logistics has evolved from an often ignored underbelly of the global economy to a hotbed of innovation, technology, and startups. Even legacy players have embraced this, with companies like Maersk, C.H. Robinson, and Kuehne+Nagel investing billions in reinventing themselves with major technology investments.

Of course, logistics technology isn't new. EDI transfers were commonplace by the 1980s, and at least some form of database management has been a mainstay for any midsize forwarder. But this progress pales in comparison to how major tech players are currently rewriting the rules for global logistics.

(continued)

It’s not just Amazon, whose combined global warehouse footprint would cover more than a quarter of Manhattan. Everyone from multinationals to startups is relentlessly optimized how both boxes and bits move around the world. But to do so effectively, a dramatically new skill set is required, across mindset, innovation targets, and actual technical skills.

Rejecting Base Assumptions

To put it simply, freight is complicated. Basic probability shows that if every shipment is supported by seven independent logistics providers, who are each successful 97% of the time, 20% of all shipments will still go wrong. To mitigate this, logistics providers, shippers, and carriers have developed complex processes and documentation requirements to avoid potential pitfalls.

But nothing is static. A modern logistics technology employee must learn to question the basic assumptions. Why do forwarders need IATA accreditation to book a shipment? Should rolled or no-show containers be a regular part of the industry? Is opaque pricing a norm? And is a personal forwarder-shipper relationship absolutely critical for shipment?

But First, Education

The flip side is that when innovation is taken to an extreme, tech employees may spend enormous effort recreating the wheel (or container). The solution is for “disruptors” to begin by educating themselves in standard practices, albeit in a challenging and nuanced industry, to reach a well-rounded level of understanding before advancing their plans.

One humbling example of this was when I spent a full year marketing a software solution for logistics providers under one category name until it became apparent during a 5-minute conversation with a forwarder that the entire industry was used to buying this type of solution “filed” under a completely different name.

On an organizational level, hiring experienced professionals and new logistics entrants can cultivate an ideal workplace to leverage a mix of expertise and innovation. On an individual level, new actors should invest in shadowing customers and service providers to better understand an industry before changing it.

Multidisciplinary Skill Set

The right approach is key. However, implementing the emergent vision requires a new toolbox too. SaaS (Software-as-a-Service) tools have changed the notion of where businesses invest resources. For example, cloud computing reshaped the global tech scene by removing a major cost center—servers—for new startups. Proper utilization of these tools, even if not at the core of a business, can free up bandwidth to focus on mission-critical issues.

(continued)

To pull from my own experience, in an annual mystery shopping survey conducted by Freightos, freight quotes are requested from the websites of the top 20 logistics providers. During the survey, just 10% of providers automatically followed up with the prospect following the initial quote. This task, easily accomplished via third-party marketing automation platforms, is proven to increase conversion rates and can be implemented by even nontechnical employees.

As a north star, familiarity with best practices of other tech companies, B2B or B2C, can drive innovation in logistics far more than many think.

Data and No-Code

Similarly, with the proliferation of structured and external data sources, independent data analysis is more important than ever. Google Sheets, Excel, and basic SQL are all key tools that can unlock huge efficiencies.

Building upon this is the rise of no-code, an entirely new form of technology that enables technical laymen to "write" their own code without programming experience. These tools frequently use graphic interfaces to connect and operate on disparate data sources. This can be invaluable for creating iterative MVPs (minimal viable products), but even when companies scale, these can continue to drive major advantages on productivity.

While goods were moved by containers 20 years ago and will continue to be moved by containers in another 20 years, the supporting processes and tactics are evolving. With a challenging mindset, industry familiarity, and the right technical skills, change can be expedited. . .hopefully expediting global shipping as well.

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Warehousing 2030

René de Koster

1 Introduction

Automation has gradually changed the type and nature of operations. Automated guided vehicles, or AGVs, were invented in the 1950s. The first fully automated warehouse system, a so-called AS/R system for automated storage and handling of pallets, was introduced in the 1960s by Demag. These systems were later further developed to also handle cases and totes (so-called miniloads). In the late 1960s and early 1970s, automated tilt-tray sorters were introduced with large sorting throughput capacities. Other breakthroughs in material handling technologies were the shuttle-based storage systems of Savoye (introduced in 2000) and the Kiva robots (in 2003), now Amazon Robotics, in which low-sized robots drive underneath the storage racks ("pods") to lift and transport them to order pick stations. Recently, applications with autonomous mobile robots (AMRs) have seen the light. These are basically a further development of AGVs. They are equipped with more sensors; have SLAM (simultaneous localization and mapping) technology, more autonomy, and decentral control; can avoid obstacles; and have possibilities for path re-optimization (see Fragapane et al., 2021).

Software also developed rapidly. Warehouse management systems (WMS), systems that manage inventory on storage locations and that guide all flows in the warehouse, are commonly used. In highly automated warehouses, they work together with warehouse execution systems that control the movements in different automated material handling systems.

Another breakthrough (around 2000) was the development and introduction into practice of mixed-case palletizing software that allows to calculate efficient stacking patterns in real time for pallets and roll cages. These algorithms allow now fully robotized mixed-case pallet stacking and are used, in combination with product

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sequencers, to create custom-built loads more densely stacked than humans could typically do this.

Recently, we have seen the advent of real-time data capturing through sensor technologies, allowing online decision-making. People and objects can be equipped with sensors, and can communicate with their environment, enabling an “Internet of Things” (IoT). Using these data in smart real-time decision-making is still in its infancy.

In the remainder of this chapter, we discuss some of these developments and provide an outlook for the warehouse of the near future. In particular, we discuss warehouse centralization and scale, various robotic technologies, collaborative robots, picking and sorting robots, the role of people and management in the warehouse, safety on the shop floor, sustainable warehouses, and IoT technologies, before we conclude. We also highlight implications for supply chain talents who are interested to pursue a career in a warehousing-related field.

2 Warehouse Centralization and Scale

Over time, warehouses have grown larger. In the USA, according to CBRE (2020), the average size of new warehouses completed between 2012 and 2017 increased from about 7060 m^2 to 17,200 m^2, while the free height increased from 8.7 m to 9.8 m, since the earlier peak in development between 2002 and 2007. In Europe and Asia, a similar growth in size can be observed. In Germany, the Netherlands, and Belgium together, 424 mega distribution centers, with a size of 40,000 m^2 and beyond, have been built between 2013 and 2019, including the mega Amazon warehouse near Dortmund of 225,000 m^2 (Buck and Bulwiesenga, 2020).

The growth in size has multiple causes. Since the 1980s, many companies have started consolidating warehouse operations. Rather than distributing products from multiple countries or states, consolidating operations in a smaller number of larger operations benefits from economies of scale and scope, reducing cost per unit shipped. In addition, assortments have grown, particularly in e-commerce warehouses, where the assortment size is not limited by available store shelf space. The degree to which consolidation pays off depends on the business, i.e., business-to-business- or business-to-consumer-type operations, and the product. Business-to-business operations typically allow somewhat longer but accurate lead times. Perishable products require short lead times and often must be stored closer to the point of consumption.

Due to the increasing competition on short lead times, particularly in e-commerce, it can now be observed that in addition to the large facilities, also smaller facilities are built, closer to city centers. As an example, Amazon recently built a cross-dock facility close to Amsterdam, allowing the company to distribute its products with very short and accurate lead times to customers in the city (Logistiek, 2020). Food home shopping has grown tremendously over the past years, partly due to Covid-19. This also has led to many new, medium-sized (5000–15,000 m^2) grocery warehouses, close to urban areas. Tesco in the UK is investing in even smaller facilities, so-called micro-fulfilment centers placed in the back of large stores, for online grocery picking (The Grocer, 2020). These centers make use of robot technologies.

The expectation is these trends remain; we will see both larger warehouses, focusing on economies of scale and scope, and also an increase in smaller e-commerce warehouses and cross-docks (including public city hubs) close to city centers, focusing on speedy delivery. In Western Europe, there is hardly space left for mega warehouses, although demand for them still exists. This may lead to multistory facilities like in heavily populated areas in Asia (e.g., Japan, Korea, Singapore, or Hong Kong). Such multistory facilities will also become heavily automated to efficiently utilize the available floor space. New robotic systems allow compacting the storage space paired with high throughput capacities.

3 Warehousing Technologies

This section discusses new automated warehouse technologies introduced in the last decades. Figure 1 (modified from Azadeh et al., 2019a) gives an overview of automated order picking systems.

3.1 Warehouse Robotics: Shuttle Systems

Several systems have been developed, deploying robots. Most of these systems are so-called goods-to-man (GtM) systems, where robots (AMRs) or shuttles (these are rail-guided and have less freedom in movement than AMRs) retrieve loads from a storage location and bring them to pick stations, after which the loads are returned to storage. The AMRs also transport loads from replenishment (restocking) stations to storage. Four types of shuttle-based, GtM systems have become dominant (with some subsystems). These are briefly discussed below, while AMR-based MtG ("man"-to-goods) systems are treated in Sect. 3.3. Azadeh et al. (2019a) give a fairly complete overview of the different robotic systems used in warehouses. Below, we discuss AVS/R ("autonomous vehicle-based storage and retrieval," also called shuttle-based storage and retrieval) systems, puzzle-based storage and retrieval (PBS) systems, mobile robotic fulfilment (MRF) systems, and hybrid shuttle/AMR systems.

AVS/R Systems

AVS/R systems consist of aisles with racks and shuttles driving at different rack tiers to retrieve unit loads (e.g., totes) from the racks at both sides of the aisles. Lifts and conveyors are used to transport the totes between the tiers and pick stations at the ground floor. Many variants exist, e.g., with centralized lifts or with lifts per aisle or with roaming shuttles that can move into the lift, travel to the pick stations with a load, and move back to another tier to store the load. Some variants allow deep-lane storage (particularly in use in production warehouses with pallet storage; see Tappia

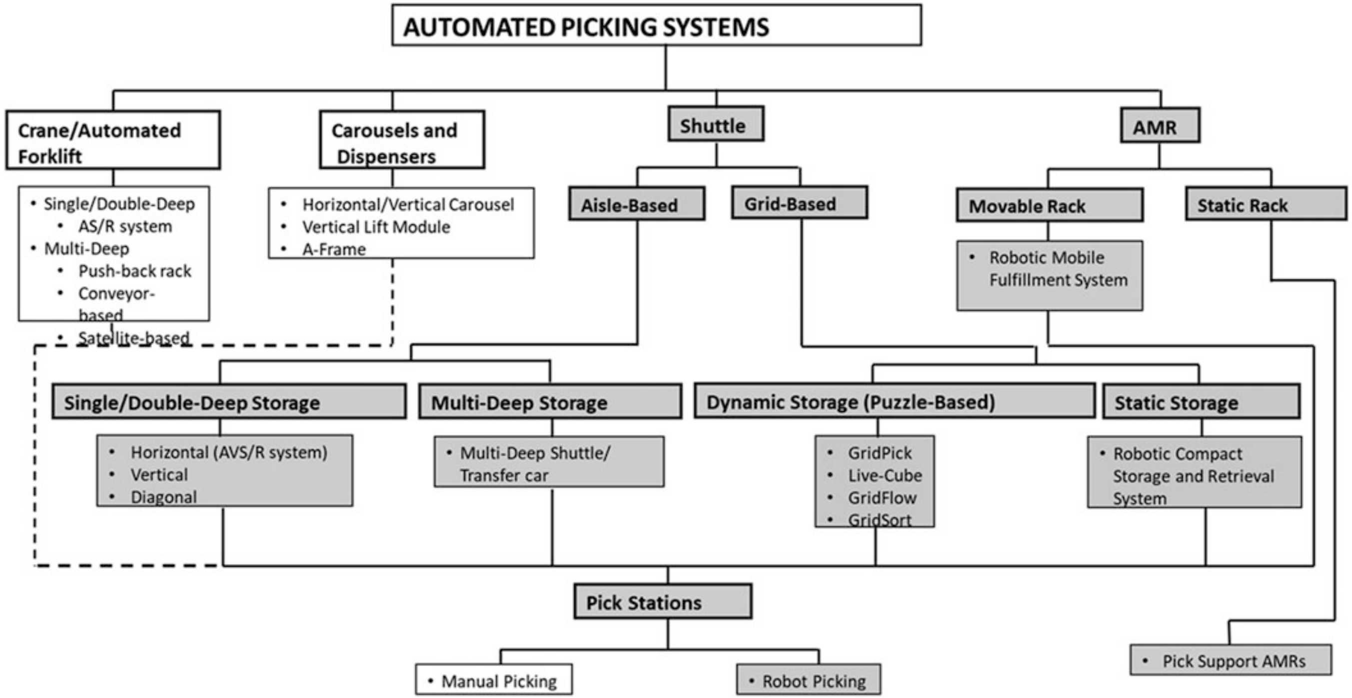

Fig. 1 Overview of automated order picking systems. Gray-shaded robotic systems are discussed in this section. Modified from Azadeh et al. (2019a)

et al., 2017). The technology for such systems has matured and all major material handling suppliers can provide them. Tappia et al. (2019) compare the performance of such systems with AS/R systems connected to pick stations and conclude that using an AVS/R instead of a traditional AS/R-based storage system yields lower investment costs in both the upstream rack system and the downstream system (i.e., smaller number of picking stations), paired with a lower total throughput time to realize a given order arrival rate. This, combined with some flexibility in throughput capacity in AVS/R systems (by adding or removing shuttles), explains why crane-based AS/R systems are less frequently used for order picking.

Malmborg (2002) was the first to analyze AVS/R systems. By now, many studies have been carried out on these systems. The performance (throughput capacity, average throughput time of an order) can be estimated reasonably well as a function of the number of vehicles (see Roy, 2011). This can be used to calculate the optimum length to depth ratio of the racks, the number of lifts required, or an adequate distribution of the shuttles across the system. Also operational policies (dwell point choice for the vehicles, vehicle to load assignment policies) can be analyzed.

Puzzle-Based Storage Systems

One of the disadvantages of AVS/R systems is that aisles are still required, occupying precious warehouse space. Recently, multi-deep systems have been developed that are even more compact. Each load is placed on a shuttle (or on a conveyor unit) that can move in four horizontal directions. Very-high-density storage is possible and transport aisles are no longer required. Only few spots must stay open to help maneuver a requested load to a lift located along the periphery of the system. Such systems are used in parking garages in major cities, on locations where land is very expensive, but also in warehouse storage and item sorting. Figure 2 shows an example. The advantage of shuttle-based storage is that multiple shuttles can move at the same time, thus achieving a high throughput. In addition, it saves a lot of space, since no transport aisles are necessary. Gue (2006) was the first to study these systems. By now, it is known how to calculate the cycle time, what the effect is of class-based storage, and what the optimal length, width, and height ratio of these systems is (Zaerpour et al., 2016). If the lift is located in a corner of the system, a cube-shaped warehouse (measured in time) almost (but not quite) minimizes the cycle time. Not only shuttles can store and transport loads, but also conveyor modules can be used, or AMRs (see Furmans et al., 2010). Nearly all literature assumes that each load is carried by an individual shuttle (or AMR). In medium-demand systems, it is much more economical to have a few coordinated shuttles work together to dig out a requested load. This is studied by Alfieri et al. (2012). However, more work on such systems is required.

Robotic Mobile Fulfilment Systems

In a robotic mobile fulfilment (RMF) system, robots (AMRs) capable of lifting and carrying movable “pods” (shelf racks) retrieve these storage pods and transport them to the pick stations. While empty, the robots can travel underneath the pods. To retrieve a pod, travel aisles are needed. The system is flexible in throughput capacity,

Fig. 2 An automated, compact parking garage. Source: avgparking.com

as more robots and pods can be added to the warehouse. It is also flexible in layout as the pods can be grouped differently in a dynamic fashion. The RMF system was conceptualized by Jünemann (1989) and was US patented by KIVA Systems Inc., which then was acquired by Amazon and rebranded as Amazon Robotics™. Today the system is operational in many Amazon facilities with more than 100,000 robots in total. Meanwhile, many other providers have entered the market with mobile racks in combination with rack-carrying robots.

Due to the rapidly increasing number of implementations, the system has drawn much attention from researchers. By now, about 15 papers have appeared in high-quality journals and many more will appear in the near future. Items covered include layout optimization, storage allocation and item dispersion over pods, product allocation to pods, allocation of orders to pods, allocation of orders and robots to workstations, and allocation of workers to pick or replenishment stations. See Azadeh et al. (2019a) for a review. The big difficulty is, however, that all problems combine and jointly impact performance (throughput capacity, response time). The work by Merschforschmann et al. (2019) studies, using large-scale simulations, the problems in combination. However, more study on integrated control policies and optimization is required, as great benefits can be achieved by taking coordinated decisions.

Hybrid Shuttle/AMR Systems

These systems are fairly recent. They combine properties of both AMR systems (like relatively freely moving in the system) with the guided movement that shuttles exhibit. Examples include the grid shuttles of AutoStore™ and Ocado™ and the rack-climbing robots of Opex™, Exotec™, and Attabotics™.

The grid shuttle systems have become very popular in practice, in a very short time. The items are stored in dense storage stacks with a grid on top. In each cell of the grid, bins that contain the items are stacked on top of each other and form the storage stacks. The workstations are located at the ground level next to the storage stacks. Robots roam on the grid, on top of the storage block. They can lift the top bin from a stack and, if necessary, temporarily place it on a neighboring stack. In this way, the requested bin can be dug out and brought to a workstation for picking. After picking, the robot (shuttle) returns it to a storage stack. The systems have become popular, e.g., in e-commerce fulfilment centers, due to their flexibility and smooth installation. It is possible to expand the grid, or the number of robots without shutting down the system. Surprisingly, little research on how to optimally design or control the system, or when to select such a system, is available. The paper by Zou et al. (2018) is an exception.

The rack-climbing robots of Opex, Exotec, and Attabotics are a new development. They eliminate the need for lifts, as the robots can access all tiers by just climbing the racks. The Exotec robots can also roam the aisles and the warehouse and transport a retrieved tote directly to a workstation. Azadeh et al. (2019b) address the problem of how to route rack-climbing robots, taking into account potential blocking and congestion delays in the rack.

3.2 Warehouse Cobots: AMR Systems

Order picking deploying AMRs is rapidly increasing in popularity. Different variants exist. In one variant a human collaborates with the AMR (or “cobot”: collaborative robot), where the cobot is responsible for all transport of the collected items and the human picks the products from the racks. Once the order pick totes, or roll cages, are full, the cobot is automatically swapped with a new cobot carrying empty pick totes. The picker can continue the pick route without returning to the depot, and the cobot automatically transports the full pick totes to the packing stations. Many suppliers now offer such pick-support cobots. The system can be introduced in a manual environment with pickers on foot, using pick carts. As the business expands, gradually more cobots can be added. In some variants the human can even be replaced by a specialized picking robot. However, due to the complexity of the picking task, particularly for items stored in shelf racks, this has not shown to be very successful yet. Optimizing cobotic order picking systems is still very challenging, for example, how to link which cobot with which picker at which point in time? For a fixed assignment, Lee and Murray (2019) solve a vehicle routing problem to minimize the time to pick all items on a pick list. “Zoning” the warehouse is another strategy: the cobots transport the order totes from work zone to work zone, until the last item has been added, after which the cobot brings the complete order to a packing station. However, also more dynamic collaborations exist, where pickers actively and dynamically have to find robots or vice versa. Azadeh et al. (2020) show that also dynamically switching the number of zones can be beneficial, especially in omni-channel warehouses with a large variety in order sizes.

To pick cartons from pallet racks, ride-on cobots have been introduced by several order pick truck suppliers. In this variant the order picker can drive the cobot-truck to a location in the pallet storage area, pick the product, and drop it in a roll cage or on a pallet carried by the truck. From this position onward, the picker can decide to walk or drive. If the picker walks, the cobot will follow the picker in close proximity. Such cobot-trucks can substantially reduce the total travel time, and, as they are only slightly more expensive than conventional order pick trucks, they are now rapidly being introduced in many carton-pick warehouses.

The system by HAIPICK™ is another interesting development. It is an AMR-based goods-to-man system which retrieves totes from a rack and transports them to a picking station. The AMR contains a lift and can retrieve multiple totes, also from high tiers, thereby collecting all totes required for the complete order.

3.3 Fully Automated Order Picking

A distinction can be made in automated picking in goods-to-man (GtM) and man-to-goods (MtG) systems. The biggest successes have been achieved in combination with GtM systems. At this point in time, it is possible for a static robot to pick mixed items from a tote that has been retrieved by a GtM system, at high speed, with relative high accuracy. The problem lies still in the variety of products. Different products might require gripper swapping (e.g., mechanical fingers or a suction head), and the right product unit has to be selected (e.g., one not partially buried under other units) to be fetched at the right position. The robot is equipped with a 3D camera which identifies the object. Two main types of identification algorithms are used, based on deep learning and training on objects, or based on a library with generalized objects and training on object geometries. The latter reduces the learning time substantially. For simple, box-shaped small products, the system works well, although human supervision is still necessary. Also in MtG systems, automated order picking has emerged. The TORU™ picking robot (an AMR) by Magazino is an example. In this variant, the AMR automatically goes to the picking location and picks the item without any help from a human. This puts some restrictions on the size, weight, and shape of the item, as well as on the way it is stored. In general, automated picking of a variety of products from locations still brings many technical problems which will not all be resolved in the coming 10 years.

3.4 Other Robot Applications

Robots are applied for other processes than order picking in warehouse and cross-dock facilities. These processes include (mixed-)pallet stacking and destacking, offloading sea containers, sorting parcels, security surveillance, and inventory scanning and management.

Not all applications are equally successful. In fall 2020, Walmart abandoned the Bossa Nova store inventory scanning and management robots, after it had previously claimed successes (Taulli, 2020). Scanning and measuring store inventory is a task that is hard to automate, since products can be stored multi-deep with limited visibility and since items can be very similar but still different. In a warehouse this may be easier, but also their inventory scanning (e.g., with drones) still requires human supervision. Two robot applications have seen a breakthrough in the last decade: surveillance and sorting. Sorting robots (AMRs equipped with, e.g., a conveyor or tilt-tray mechanism) were used in manufacturing on a small scale and were introduced in China by several parcel carrier companies in large-scale applications, with hundreds of sorting robots. They require less floor and building space than a conventional cross-belt or tilt-tray sorter, which makes them rapidly cheaper for not too high throughput capacity requirements (Zou et al., 2021). They also allow flexible layouts as it is possible to increase the number and position of input stations dynamically. Also the allocation of robots to inputs and outputs can be changed dynamically. This allows the system to cope with temporary peaks.

4 Impact of Recent Trends

This section discusses three recent trends: continuing focus on safety and labor circumstances, sustainable warehouses, and use of Internet-of-Things technology in the warehouse.

4.1 Safety

Warehouse safety is receiving much attention from practice and research. The reasons for companies to engage in worker safety vary, but they include the high costs resulting from having non-safe work environments (e.g., direct and indirect costs from accidents), the belief that safe work environments align with performance (productivity and quality), and the desire to create good and stimulating work environments. In Western Europe, the latter factor is also triggered by the ageing work force and the shortage of qualified personnel in specific regions. Research has demonstrated that the company's safety culture and the warehouse leadership have an impact on worker behavior and thereby on accidents (De Koster et al., 2011; Hofstra et al., 2018). According to work of De Vries et al. (2016c), the manager's prevention focus is associated with a reduced number of accidents, and focus on safety does not trade off with productivity.

Increased automation may also be instrumental to create a better safety climate and to reduce accidents. Most automated equipment strictly separates human from automated work. On the other hand, collaborative robots introduce a new risk as people and robots work simultaneously in close proximity. Such robots therefore move at low speeds to reduce the risk. It is somewhat surprising that particularly the robotized US warehouses of Amazon (which have a GtM operation with physical separation of people from robots) have high accident rates per employee (Evans, 2020). These accident rates are strongly correlated with high peak loads and work stress (Evans, 2020).

Still, with proper deployment, it should be possible to lower the per capita accident rates in automated facilities. Proper robot deployment may also help to create and maintain distance between workers in times of a pandemic.

4.2 Sustainable Warehouses

According to the Global Alliance for Buildings and Construction (2018), buildings (39%) and distribution processes (23%) are a large source of global greenhouse gas and fine particle emissions. For the buildings, this is both through the production of the materials and the construction process (11%) and through the building operations (28%). A large part of the building sector emissions is from carbon, embodied in the buildings (28%), which come available over time. A sizeable percentage of these buildings include warehouses. Operational emissions can be reduced in several ways and most of these go hand in hand with reduction of cost of energy. It is not surprising that many new warehouses in Western Europe apply for BREEAM, LEED, or other sustainability certificates. Embodied carbon can be reduced by going for circular buildings, where use is made of recycled materials and components and where the building can be disassembled into reusable materials and components. The objective is to have a complete circular, environmentally neutral building. This is, however, still in its infancy.

The most popular measures that are gradually becoming a standard include using bioclimatic architecture (shape and orientation of the building), using renewable heat and power (e.g., by equipping the roof with solar panels and storing redundant energy), taking measures to boost energy efficiency (e.g., insolation of buildings, high-performing glazing and windows, minimization of thermal bridges at loading docks, LED lighting, using more energy-efficient material handling equipment), increased recycling, and recovery of energy (heat recovery) and materials (e.g., packaging materials, or water). The major next step is to become a net energy producer.

Part of the measures that should be taken for a BREEAM certificate overlaps with measures that are needed to secure a safe workplace (e.g., separation of traffic flows), or are needed to comply with general laws (waste separation), and are therefore beneficial in general. As sustainability becomes more closely tied with corporate reputation, governmental regulations tighten, and investors and developers aim for future-proof facility portfolios, carbon-neutral warehouses and facilities running on clean energy will gradually become dominant.

4.3 IoT in the Warehouse

Internet-of-Things (IoT) technologies are based on continuously sensing and capturing process data and communicating these between connected actors and devices. The objective is to use these data to optimize decision-making. Many data are kept, stored, and used for process control in warehouses. This started some decades ago with paperless warehouses where, e.g., pick instructions were conveyed to workers via mobile devices such as RF terminals with scanners or pick-by-light or pick-by-voice systems. Nowadays, also pick by AR (augmented reality) glasses are deployed in some warehouses. With such systems, workers can interact with their environment, and, particularly in exception situations, work can be rearranged, or exception measures can be taken. All activities are time-stamped and can be used for individual performance analysis and improvement (e.g., via feedback and incentive systems). It is also possible to optimize the work, taking into account differences between individual workers, the work content, and the work environment (see Matusiak et al., 2017, for an example). Not only order pickers wear communication and sensing devices, these can also be mounted into equipment, such as warehouse trucks. The trucks use a log-in system, so workers can be identified and tracked. Trucks can be equipped with shock detectors and part wear sensors, to track safe behavior and to plan maintenance. In warehouses that use large AMR fleets, the robots have to be able to detect obstacles and other vehicles. They have to communicate, and for large fleet sizes, it is better to use decentralized control in, e.g., path planning (see Fragapane et al., 2021).

In spite of these developments, products and warehouse locations are rarely equipped with sensors or communication devices (not even passive RF tags), and control and planning of human operators is still centrally organized. The full use of all IoT possibilities will only become manifest when good business cases will be shared.

5 Human Factors

In the foreseeable future, people will still be needed on the shop floor, even in highly automated environments. People are inexpensive, fast, accurate, flexible, and able to solve problems. However, the business requires more and more 24/7 operations and flexibility in the volumes that need to be handled and shipped. Part of the work will be carried out by automated equipment and robots, but the remainder must be done by people.

The big challenge for management is therefore how to redesign the work in collaboration with robots and how to retain, motivate, and stimulate people to carry it out. The way individuals behave in warehouses largely determines performance. The set of factors determining this is called "human factors" (Bendoly et al., 2006). Grosse et al. (2015), differentiate warehouse workers based on factors, *physical factors* (e.g., posture), *mental factors* (e.g., learning, forgetting), *perceptual factors* (e.g., human information processing), and *psychosocial aspects* (e.g., motivation, stress, or regulatory focus), as these factors directly impact the performance. Vanheusden (2020) also includes *picker skills* as a factor. These human factors interact with, e.g., incentives, goal setting, and feedback and jointly determine task performance. However, research on how to integrate this in operational warehouse planning systems, and on what the effect is on humans in a collaborative automated environment, is still very limited. Examples of such research include Batt and Gallino (2019), De Vries et al. (2016a, b), Glock et al. (2019), Larco et al. (2017), and Matusiak et al. (2017). We here summarize some well-known results on which measures may interact with human factors to help stimulate performance.

Goal Setting Productivity can be increased by setting challenging (but not too challenging) goals in repetitive work (see the meta-analysis of Locke & Latham, 1990, and the paper by Doerr & Gue, 2013).

Incentives, Nudging, Gamification Incentives (e.g., geared toward productivity or quality) work in enhancing performance, but the way they are formulated has impact. The impact may be different for different people, depending on behavioral traits, such as regulatory focus (Higgins, 1997, 1998). De Vries et al. (2016a) found that in a parallel order picking system (MtG picking), competition-based incentives lead to higher productivity than cooperation-based incentives, for people with a dominant promotion focus. In a sequential zone picking system, cooperation-based incentives are more productive. To apply these findings, managers may reassign employees with a particular regulatory focus to tasks that are better aligned with their regulatory focus.

Feedback Public quantity feedback helps to increase productivity, in particular for bottom-ranked workers (Zhang et al., 2021; Song et al., 2018). Public feedback can be given in different forms, e.g., via Andon sign boards, but also other forms of feedback work. Schultz et al. (1999) and Powell and Schultz (2004) show that workers adapt their speed based on visual signals in serial systems, to avoid downstream workers to become starved, or based on a visual backlog (inventory).

Although these measures work in isolation, the question is whether they also work sustained and how different measures interact with each other and with the above human factors of the workers. So far, experiments reported in the literature are carried out in nonautomated, manual environments. It is largely unknown how these measures work out in combination with collaborative robots in order pick processes. Pasparakis et al. (2021) carried out an order picking experiment with collaborative robots. It appears that the "human leading" in the collaborative order pick tasks leads to higher system productivity compared to the "robot leading." This negative effect of the robot leading is partly mitigated by the worker's "prevention" focus. However, much work still needs to be done.

6 Conclusion

This chapter discusses some recent developments in warehouses that have manifested in the last decades. These developments will continue in the decade to come. We see both centralization and decentralization trends, more automated storage and order picking systems that require a reduced footprint, several new types of robot systems, increased emphasis on sustainability, safe working environments and IoT applications, and attention for human factors. Although these developments have received some research attention, much work is still to be done. Still, important relevant insights have been obtained, which may help managerial decision-making. They are summarized below.

1. Warehouse centralization. Little research is available into under which conditions (both supply and service-related) it pays off to centralize or decentralize with a single- or multi-echelon structure and when to locate close to customers. However, particularly for e-commerce companies, the ability to deliver in tight time windows, with very short lead times, may offset the increased costs of facilities, handling, inventory, and (sometimes) transport. Such centralization decisions must be taken carefully on per market basis.
2. Warehouse robotics systems, including GtM and MtG systems. New robotic systems still emerge continuously. Recent examples include rack-climbing AMRs, unit load retrieval AMRs, and robotic sorting systems. The question is how to deploy, plan, and control these systems, how to analyze these systems for operational and economic performance, and how to select the right system from a portfolio of options. Some tools are already available to compare particular systems for performance, while new models emerge continuously.
3. Human factors. It is largely unknown how people respond to working with robots or how to deploy people in working with robots. The ultimate idea was to automate the boring, repetitive, or heavy part of the work. But what can be seen from some implementations is that people do the part that was difficult to automate, but which now has become much more monotonous and repetitive to execute, as the robots are doing the "fun" part (see, e.g., Scheiber, 2019). Managers must try to maximize joint productivity and focus and on how to design jobs in a sustained fashion balancing worker and system objectives.
4. Safety. Researchers have been trying to link safety on the shop floor to higher productivity and quality levels. This has proven to be difficult to demonstrate, as short-term effects may lead to lower productivity, while long-term effects may be positive (De Vries et al., 2016c). In a recent paper, Pagell et al. (2020) demonstrate, based on a 25-year longitudinal database, that organizations that provide a safe workplace have significantly lower odds and length of survival. However, their research leaves the question of a possible trade-off between warehouse safety and warehouse performance unanswered. As in many environments it is important to retain engaged warehouse workers, managers should focus on creating a safe working environment. According to De Vries et al. (2016c), this leads to a more satisfied workforce and it is not offset by a lower productivity.

5. Sustainability. Circular warehouses are still far out. However, on the short term, many warehouses are going for sustainability certificates, in line with higher company objectives, to reduce long-run costs. On the other hand, higher levels of automation consume much more energy. It would be interesting to find out how to optimize energy consumption of highly automated warehouse systems and to what extent more sustainable warehouses also deliver better operational and cost per unit performance. In any case, warehouses have a great opportunity to lower energy bills by investing in sustainability.
6. IoT. IoT (and other) technologies will undoubtedly penetrate further on the shop floor and benefits are to be expected. Still, except for some examples, the benefits of integrating real-time data into real-time distributed optimization are not yet fully convincing. More is to be expected in the coming decade.

Warehousing in 2030 will not differ much from current warehouse operations. Many trends are already visible now and will become even more clear in the future. But, like the Covid-19 pandemic affecting many operations on a global scale in an unforeseen way, the future may still bring new and unexpected developments.

Management Perspective on the Warehouses of the Future Will Be Automated and Sustainable

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The saying "the future is always beginning now" has never been so relevant. One of the biggest revolutions in the history of the industry is taking place right in front of our eyes. Digitalisation and automation are taking hold in every facet of production and logistics and are altering processes from the ground up. The speed of this development eclipses almost everything that has gone before. It frightens some people. It is certainly associated with challenges. But above all, it holds incredible opportunities that, if seized, will make work in the warehouses of the future more efficient and more sustainable—and therefore better.

In the warehouses of the future, everything will be interconnected, will communicate with each other and will be in motion—transparent, and exactly according to plan, but still flexible. Digitalisation and automation will further accelerate intralogistics and at the same time make it safer, more predictable and thus more productive. It's only natural: People looking to automate want to reliably reproduce recurring processes based on defined standards. This desire is almost as old as humanity itself. The ancient Greeks paid homage to Automatia (also known as Fortuna), the goddess of events that occurred without human intervention. They referred to these events as "occurring freely". Today, the German DIN standard V 19233 summarises this "free

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occurrence" of technology in sober administrative German as equipment or a facility that "operates as intended, in whole or in part, without human involvement".

The warehouse is one of these "facilities" in which automation is already particularly advanced. Intralogistics is considered one of the key components of the fourth industrial revolution, and not without reason. Warehouse equipment, material handling equipment and software now form a single entity in which man, machine and material flow cooperate with and complement each other. Today, solution providers for intralogistics also have to be engineers and software developers—like we are at Jungheinrich. Outside warehouse and production facilities, self-driving vehicles are still a vision of the future. Inside facilities, automated guided vehicles (AGVs) are now the state of the art and one of the fastest-growing segments.

Fully automated high-bay warehouses are another application. These deserted halls, up to 40 m high, are being built all over the world. In them, stacker cranes handle all warehouse processes completely independently. The warehouse management system controls incoming goods, order picking and outgoing goods, while the stacker cranes automatically store and retrieve containers or pallets. The systems can operate around the clock—no more breaks, no more downtime and no more light switches. The stacker cranes work in absolute darkness and people only enter these warehouses when something needs to be repaired.

Many people feel uneasy about the fact that, at first glance, humans no longer seem to play a role within these closed systems. AGVs and fully automated high-bay warehouses have become focal points for the new fear about the end of work. But the opposite is true. In fact, automation does not mean that human labour in the warehouse is being phased out. Instead, it will be upgraded. People and technology will work less "hand in hand" than they do today and will instead be increasingly connected "mind to mind". People will be freed from repetitive routine tasks and will have to drive, pack and pick less, but they will have to monitor and manage the digital systems in their working environment to an increasing extent and thus control the big picture.

This is also necessary. Human labour has become a scarce resource. Dealing with this in a sustained manner is the order of the day because the shortage of skilled workers is a reality and no longer limited to academic professions. Skilled workers and forklift drivers are also desperately needed—not only in Germany. Here, automation provides an opportunity to make warehouses more efficient, and therefore more sustainable. This also applies to other areas: automated processes reduce the risk of errors, prevent accidents and reduce unnecessary movements. Indispensable building blocks for greater energy efficiency and climate protection are central requirements for the warehouse of the future.

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Automation is not an end in itself. It offers concrete added value for logistics as a whole but above all for those who trust in it. Individuality will play an increasingly important role. The advent of the Internet of Things (IoT) and artificial intelligence (AI) makes it possible to find the right solution for every application. Especially in intralogistics with its many interconnected process steps, each of which must be well-described and expressed in data, this opens up completely new possibilities. Off-the-shelf solutions will no longer be sufficient for the warehouse of the future. Understanding of a customer's needs and detailed analysis of their specific material flow will be at the beginning of any warehouse redesign. The result will be more efficient, more sustainable and therefore ultimately better intralogistics. This is what we stand for at Jungheinrich.

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Future of Procurement

Insights from a Global Survey

Christoph Bode, Davide Burkhart, Ruth Schültken,
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Key Facts

- Cost is still the dominant objective in procurement organizations: 62% of respondents rate it as the first or second most important objective.
- Only 9% see their procurement organization as a good example of sustainable practices.
- Currently, most companies try to consolidate their supply base—but only 47% have kept their overall strategy during the pandemic.
- Budget restrictions and change management inertia are the largest performance roadblocks for procurement.
- Most procurement organizations have a digitalization strategy—but satisfaction with it is rather low.
- Most organizations rely only on their direct suppliers to monitor the supply chain.
- Employees are more satisfied with their procurement organization when there is a higher level of entrepreneurial orientation.

1 Introduction

Since the first documented appearance of the term "supply chain management" in 1982 (Oliver & Webber, 1982) (its roots were certainly established earlier, especially in the field of logistics), the idea of a concerted, collaborative management of the flows of materials, information, and funds along the different value-adding stages of

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a product (or a service)—from the raw material supplier to the end customer ("supply chain")—has had a tremendous impact on business research and practice. Today, it is hardly possible to find industrial firms that do not consider "supply chain management" aspects in their strategic, tactical, and operational planning, or in their overall business strategy (Fisher, 1997). Although the "chain" metaphor is arguably misleading because it falsely suggests a linear, tiered pattern instead of a network of interconnected firms, "supply chain management" has established itself as the common term for a broad and eclectic research field that spans many academic disciplines and corporate functional areas and often blurs their boundaries. From a research perspective, this is evidenced by the large and heterogeneous range of academic journals that publish supply chain-related research, and, from a practical perspective, there is a tendency to use the term supply chain management as an umbrella concept for all sorts of primary value-adding activities. For this reason, it is important to remember that the initial idea of supply chain management was that by effective coordination and collaboration, firms connected in supply chains are able to reach a higher level of value creation that none of the individual firms could reach on their own (Anderson & Narus, 1990). Essentially, supply chain management is about optimizing supply and demand across firm boundaries and about managing interorganizational relationships. Although the corporate procurement function is a core element of this idea, it has often failed to play an active role in its successful implementation. A reason for this failure lies in the dominant paradigm by which procurement's identity has been traditionally defined: cost reductions. To some extent, this narrow paradigm was not merely imposed by other functions or by top management, but a result of procurement's own excessive cost reporting metrics (savings). While the focus on cost is not wrong per se—after all, purchased materials and services make up between 50 and 80% of a product's (or service's) total cost in most industry—the myopic view on cost has refrained procurement from really contributing to the supply chain management idea and also from gaining more visibility and clout in the upper echelons of organizations. The result is epitomized in Jack Welch's infamous quote that "Engineers who can't add, operators who can't run their equipment, and accountants who can't foot numbers become purchasing professionals." This quote, however, is from the last century, and the future of the corporate procurement function will likely be different.

The procurement function faces particular challenges when the supply chain is impaired in order to procure the necessary goods and services in the required quality at the right time for the best possible price. While this tension is not new, the challenges increase in times of crisis. For example, virtual collaboration from the home office brings new challenges for employees, business partners, customers, and companies. At the same time, procurement is in a state of upheaval due to digital transformation. Strategies are being rethought, and new business models are being developed, so that digital disruptions could also go from being the exception to the rule. For firms that seek to be successful in the future, it is more important than ever to understand customers and their needs and to offer targeted solutions. Furthermore, transactional but also tactical and operational tasks are supported or automated by new technologies, resulting in a shift to more strategic, value-generating content, as simple operational tasks, such as processing orders, are increasingly taken over by software. This poses additional challenges for procurement staff, who on the one hand have to understand, operate, and learn new systems but also take on new tasks such as monitoring IT systems, adapting or creating algorithms, developing strategic plans for and with the business units in the company, driving innovation with suppliers, hedging risks in the supply chain, or ensuring sustainability with regard to purchased products (Frey & Osborne, 2017).

Today's procurement function of a company is therefore challenged to recognize new trends and technologies, to make them usable and thus to bring about a value contribution for the success of the business model. To this end, the following sections examine the status quo and some future directions of procurement based on an empirical study and discussions with executives. A special emphasis lies on the current and future goals in the examined procurement organizations along several company strategies. Our findings indicate that procurement is playing and has a key role to play in responding to the COVID-19 pandemic. This role is multifaceted and multidirectional, involving both collaborative and competitive actions with suppliers, driving a nuancing of existing global sourcing strategies and advancing digital procurement capabilities. Procurement does indeed have a boundary spanning role that involves active inventory management with suppliers, reallocating orders across the supply base, and developing response to demand risks with suppliers. Procurement is not solely focused on supply risks but also involved in responding to demand risks and other risks, including manufacturing and logistics risks (van Hoek, 2021). During the last decade, practitioners and researchers have increasingly recognized that procurement contributes value to business performance beyond reported cost reductions, though capturing and evaluating such contributions is often challenging. The solution for procurement to expand its recognition beyond cost savings needs to unfold along two directions: (1) Procurement must change its narrative, paradigm, and associated self-conception; and (2) procurement needs to develop metrics that are meaningful across multiple areas of the business and communicate the multiple contributions to firm and supply chain success (Ueltschy Murfield et al., 2021).

2 Status Quo and Future of Procurement

The purchasing function and the associated processes can take a wide variety of forms (Bäckstrand et al., 2019). In order to provide a well-founded outlook on the future of procurement, we investigated the current state of the procurement function and several trends structured according to Harold Leavitt's "diamond model" (Leavitt, 1965). This parsimonious framework features five dimensions—"strategy," "processes," "organization," "technology," and "people"—and has been widely used to describe and study influences on organizations in a structured fashion (e.g., Burke, 2017; Webster & Wind, 1972).

Table 1 Sample characteristics

Variable	Levels	#	%
Revenue	Under $50 million	29	7
	$50 million–$249 million	44	11
	$250 million–$499 million	23	6
	$500 million–$1.19 billion	31	8
	$1.20 billion–$3.99 billion	37	9
	$4 billion–$9.99 billion	40	10
	$10 billion–$14.99 billion	19	5
	$15 billion–$24.99 billion	24	6
	$25 billion–$34.99 billion	18	5
	$35 billion–$44.99 billion	14	4
	$45 billion or more	37	9
	NA	77	20
Employees	Less than 100	18	5
	100–499	40	10
	500–1999	57	15
	2000–4999	44	11
	5000–9999	32	8
	10,000 or more	137	35
	NA	65	17
Location	North America	211	54
	South and Central America	8	2
	EMEA	55	14
	Australia	4	1
	Asia	53	13
	NA	62	16
Seniority	Chief Procurement Officer (CPO)	42	11
	Vice President Procurement	33	8
	Director Procurement	84	21
	Manager Procurement	104	26
	Procurement Practitioner	52	13
	Others	17	4
	NA	61	16

The methodological approach consisted of two parts. After conducting an online survey, the results were discussed with procurement executives through various channels, such as video calls and webinars. The online survey has been fielded from mid-December 2020 to early May 2021. In this time bracket, a total of 817 procurement executives and practitioners participated in the survey, yielding a heterogeneous sample of 393 complete data points from a broad range of industry sectors and firm sizes without indications for systematic biases. Table 1 provides an overview of the sample characteristics.

2.1 Strategy, Goals, and Value Contribution

The procurement function contributes significantly to corporate performance. Since the 1980s, there have been efforts to align purchasing more strategically (Kraljic, 1983); however, it is only in the last 15 years that purchasing has gained more strategic importance. Top managers, practitioners, and researchers are now aware that they can derive greater competitive advantage from procurement beyond reported cost reductions, though capturing and evaluating such contributions is often challenging (Ueltschy Murfield et al., 2021). The level of value contribution generally depends on the interaction of procurement efficiency, understood as the alignment between procurement strategy and capabilities, and strategic integration of purchasing, which reflects the degree of alignment between procurement and business strategy. Therefore, to ensure that the functional objectives of procurement are aligned with the business strategy, the procurement function should be integrated into the strategic planning process of the entire enterprise (Gonzalez-Benito, 2007).

In practice, a procurement strategy may include cost-saving goals to improve a company's operating margin, goals to generate supplier innovation for production, automation goals to improve the efficiency and effectiveness of the procurement process, compliance goals, and/or goals to standardize IT systems. From our discussions with executives, the perception of the value contribution of the procurement function is shifting toward securing supply by building sustainable and resilient supply chains. However, the procurement function is still closely linked to cost savings by itself, other functions, and top management. One of the main reasons behind this is seen in the performance measurement and metrics used to incentivize procurement practitioners and executives (Ueltschy Murfield et al., 2021).

Building on the competitive priorities framework for procurement (Krause et al., 2001; Ward et al., 1998), we asked participants to rank the procurement objectives "cost," "quality," "risk," "speed," "innovation," and "sustainability" in the order of importance to their company's top management. To investigate the internal metrics and the direction where the respondents think their functions are heading, we asked for the ranking of the objectives today and in 5 years. The current performance metrics, as shown in Fig. 1, indicate that procurement is and will probably remain cost driven in the short term. Today, 62% of the respondents report "cost" as the first or second most important measure for the top management. Furthermore, although sustainability has received a huge amount of attention in the last years, when performance objectives are pitted against each other, "sustainability" ranks last. Unsurprisingly, only 9% of the participants see their procurement organization as a good example of sustainable practices.

The ranking in 5 years, as seen in Fig. 2, does not show a huge change in the overall distribution of the objectives from the current ranking. "Sustainability" and "innovation" will receive more attention of the procurement functions, as roughly twice as many respondents rank these objectives as first or second. However, they still rank last in comparison to the other objectives.

In a follow-up analysis, we investigated the distribution of the ranked objectives depending on the overall company strategy. Following a common typology, we

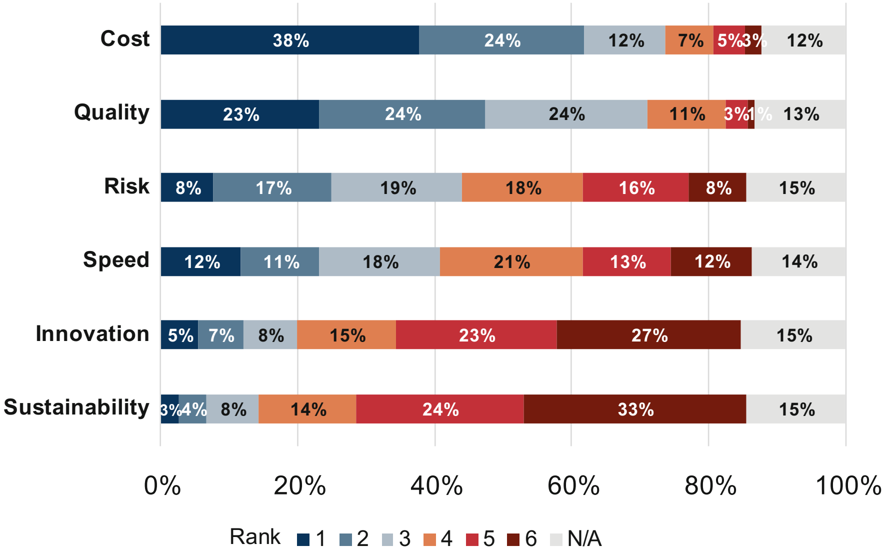

Fig. 1 Ranking of procurement objectives today in the order of importance to the company's top management

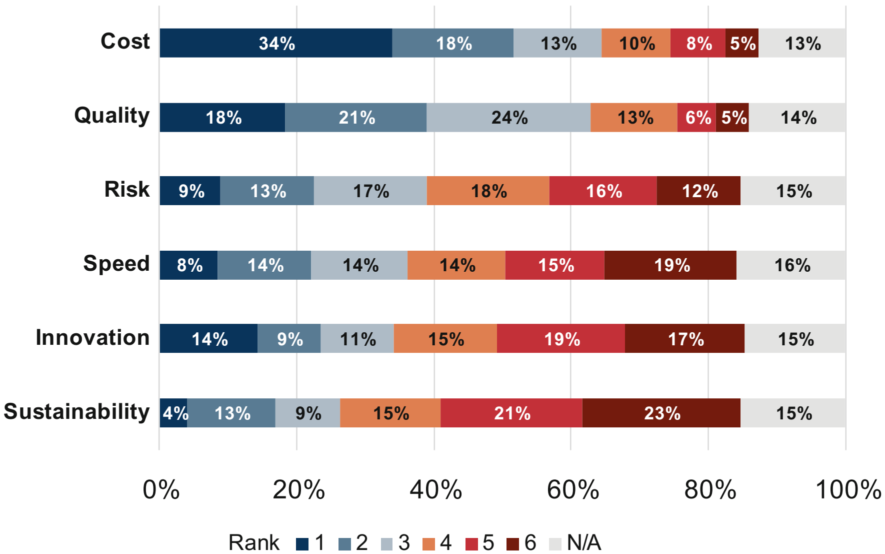

Fig. 2 Ranking of procurement objectives in 5 years in the order of importance to the company's top management

asked the respondents to indicate whether their company is a “prospector,” “analyzer,” “defender,” or “reactor” (Miles et al., 1978). The sequence of the objectives in the respective strategy was quite consistent with the overall distribution in Fig. 1. Procurement functions of “defenders,” which aggressively defend their market niches by improving their efficiency and effectiveness, ranked “speed” on average higher than “risk.” Further, procurement functions of “prospectors,” which aim to be first to market with most innovative products or services, and “analyzers,” which follow a middle strategy between “prospectors” and “defenders,” show the same distribution as the overall rank order in the shown figure. Lastly, procurement functions of “reactors,” which have no clear long-term patterns of decision, rank “speed” significantly higher at on average third place after “cost” and “quality.”

The changing focus of the procurement function together with the COVID-19 pandemic will influence the collaboration with the suppliers, i.e., the overall supply base strategy. With approximately 51%, most of the respondents indicated that they currently pursue a consolidation (9% significantly and 21% slightly) of their overall supply base. On the other hand, 31% of respondents pursue an expansion of the supply base (4% significantly, 17% slightly). Just 7% do not want to change their supply base strategy. However, the supply base strategy seems to be quite dynamic in current times, as just 47% kept their overall supply base strategy during the COVID-19 pandemic.

2.2 Procurement Organization

Procurement processes strongly shape the procurement organization. Further, they are subject to constant transformations, as existing structures have to be adapted to a constantly changing environment. The optimal design is typically reviewed by executives when the structure of the organization changes (e.g., due to mergers or acquisitions), when changes in operations require it (e.g., due to digitizing processes or reconfiguring the supply network), or when executives notice signs of ineffectiveness (e.g., new product introductions take long to scale) (Alicke et al., 2020).

The organization of a procurement department can be described, among others, by the level of centralization, the level of hierarchy, and the reporting structure. In practice, purchasing departments are usually centralized and hierarchical. In our study, 61% of the procurement organizations are centralized regarding the decision-making authority, 11% hybrid, and 26% decentralized. The respective authority structure is rather hierarchical in 58% of the procurement organizations, medium in 18%, and not hierarchical in 22%. While there are predominant organizational designs regarding centralization and hierarchy, the reporting structure is more diverse. Procurement can be under the responsibility of the Chief Financial Officer (CFO) (24%), the Chief Executive Officer (CEO) (17%), the Chief Operating Officer (COO) (16%), the Chief Supply Chain Officer (24%), or other functions and executives (18%).

The organizational design must take into account the challenges of the procurement department to meet them as well as possible. Our survey showed that the biggest roadblocks to higher performance of the procurement organization are budget restrictions and the change management with stakeholders. 19% of the respondents consider budget constraints a large roadblock (17% very large), and 24% of the respondents evaluate the change management with stakeholders as a large roadblock (13% very large). Further challenges that will come up in the future will shape the organizational design and make reconfigurations necessary. Reconfigurations of (procurement) organizations usually start with a benchmark, followed by an attempt to replicate well-functioning structures to motivate employees to support the change. However, not only challenges drive the organizational design but also trends and innovations like new technologies.

2.3 Digital Transformation and Technologies

Procurement organizations are particularly working on intelligent automation of their processes to increase productivity (Högel et al., 2018). Digital technologies have the potential to revolutionize the procurement function. Significant improvements in the cost of computing power, combined with potentially disruptive technologies such as blockchain and artificial intelligence, have created multiple opportunities. New technologies can be used to optimize spend and monitor high-risk suppliers. Further, tracking products in real time across the supply chain becomes easier, while associated tracking and authentication costs decrease. In addition to incremental material cost savings of 5–10% and productivity gains of 30–50%, significant improvements in innovation, quality, process reliability, speed, and risk management are achievable. Despite this, most companies' procurement functions are still living in the analog past, performing operational tasks manually, making decisions without a comprehensive understanding of data, and lacking visibility into the sources of product parts (Högel et al., 2018).

The starting point of a digital transformation should be the formulation of a strategy to drive the necessary changes. Of the participating procurement executives and practitioners, only 60% state that they have a digitization strategy for the purchasing function, while 28% have no strategy at all. Additionally, merely 15% of the respondents are satisfied or highly satisfied with their strategic approach for digitalization in their procurement functions, and 46% are dissatisfied or highly dissatisfied. A lack of a digitization strategy and a general dissatisfaction with the approach taken can be an indication that the purchasing function is not yet geared to future challenges, even though over 55% of the respondents state that digital transformation is critical to success and will have a greater impact on the purchasing function in 2021 than in 2020.

There have also been calls that the digital transformation in procurement should not just deal with the own function. Instead, suppliers and supply chain partners should be included, and therefore, a rather dyadic view of digital transformation should be adopted (Kosmol et al., 2019). Many processes can be automated on the basis of cross-company digitization. In procurement in particular, automation is a core component of the digital transformation and will lead to automated operational, administrative, and tactical tasks (usually activities of operational purchasing). Complete ordering and reordering processes, including billing information, can be designed and automated on a paperless basis using consumption data. However, as mentioned before and also according to discussion with executives, a main requirement for the automation of ordering processes is the establishment of business networks for collaboration and the exchange of information between companies, suppliers, and beyond.

2.4 Procurement Processes

For Chief Procurement Officers (CPOs), procurement processes concern, among others, the “source-to-pay” process that covers all areas starting with the demand, through the supplier selection and management process, category management, awarding, contract management, order processing, and the invoice processing and billing process. They implement modern applications to automate the workflows in order to be able to focus on the increasingly strategic tasks (Umbenhauer et al., 2019). Automating these processes leads to a significant increase in data quality and data availability, as well as increased compliance and transparency in the procurement processes, which can result in a significant reduction in operational risks and process costs. Nevertheless, 13% of the respondents of our survey state that the availability of data is a large roadblock to the performance of their procurement organization (8% very large). Data quality is seen as a large roadblock by 11% of the respondents (12% very large). Thus, there is room for improving process monitoring by increasing process automation.

The sub-processes “source-to-contract” and “procure-to-pay” as well as the associated activities are usually not always completely assigned to the purchasing department. Despite the stringent process model, some challenges arise in practice. Problems cited by executives and practitioners include manual ordering, contracting, and manual document handling, as well as process interruptions and breaks. To effectively eliminate these process frictions and create process flow, companies need detailed insights into their operational environment. They need to identify the critical process paths for each core task, locate deviations, and correct their course on an ongoing basis by continuously monitoring the overall process.

The processes to be considered by procurement should not be limited to the own organization. In this regard, also the processes of suppliers need to be monitored by procurement to ensure compliant behavior. The predominant form of monitoring indicated by the respondents of our survey is indirect monitoring, that is, reliance on tier 1 suppliers to monitor their subcontractors to make sure they comply with the code of conduct. A share of 8% relies to a large extent on indirect monitoring (13% very large). Indirect monitoring is followed in frequency by direct monitoring (i.e., on-site audits); 6% rely to a large extent on direct monitoring (11% very large). Third parties are least often used to monitor supplier processes; 5% rely to a large extent on their evaluations (10% very large). In general, procurement organizations should put more emphasis on their supplier monitoring processes, as consumers are demanding more transparency in the supply chain and even show a higher intention to buy when companies are disclosing their supplier monitoring activities (Duan et al., 2021).

2.5 The People Side of Procurement

Technologies, changes in strategy, organization, and processes have direct and indirect impacts on employees in procurement. As their tasks and responsibilities shift, the required skills also change. This leads to a constant demand for internal and external talents. In our survey, 24% of the respondents evaluate internal talent and knowledge shortage as large roadblock (6% very large) to the performance of their procurement organization. External talent shortage is stated as a large performance roadblock by 16% (8% very large). Compared to the results of the previous study, talent and knowledge shortage seems to be becoming less critical. In 2020, 42% of the responses evaluated internal talent and knowledge shortage as large roadblock (3% very large), and 43% rated external talent shortage as large roadblock (2% very large). Although the demographic challenges of a shrinking overall population are impacting the talent pool in many developed countries, recruiting in procurement seems to improve. A possible explanation might be that the shift of the focus from saving cost to creating value by securing supply and building sustainable and resilient supply chains goes along with a similar shift in the job expectations of young employees. We recently conducted a study among operations management students that stated that an interesting, purposeful job is more important than high salary. The rethinking of both procurement goals and job expectations might make procurement more attractive to the new generation. The increase in the share of respondents evaluating the shortages as very large roadblocks might be explained by the demand for specialized knowledge required due to the recent developments in procurement, e.g., increasing automation, that cannot be met yet.

While recruiting becomes less of a problem, working in procurement is more and more polarizing. In this year's study, 37% of the respondents would recommend working in their procurement organization likely or extremely likely, equally to the results of 2020s study. Simultaneously, the share of the respondents that would not recommend it to friends or colleagues increases from 19% to 28%. When differentiating the respondents according to their entrepreneurial orientation that analyzes their proactiveness, autonomy, risk-taking, and innovativeness (Hughes & Morgan, 2007), it becomes clear that these are crucial characteristics for the employees in procurement: 52% of the respondents with a high entrepreneurial orientation are satisfied or highly satisfied with their procurement organization, while only 10% are unsatisfied or highly unsatisfied. For the respondents with low entrepreneurial orientation, the relationship seems vice versa: 50% are unsatisfied or highly unsatisfied, while 18% are satisfied or highly satisfied and would recommend their organization to friends and colleagues. Due to ongoing changes in procurement, employees must be retrained in training and development programs or assigned to a different job (Gonzalez-Benito, 2007). Respondents with low entrepreneurial orientation might support these changes less than respondents with high entrepreneurial orientation, resulting in lower satisfaction with their procurement organization. Thus, procurement should not only aim to recruit people with high entrepreneurial orientation, but it should also provide the room to unleash the entrepreneurial potential of procurement employees. According to the assumption that the change in procurement fits the new generation's changing aspirations for their jobs, this should become increasingly feasible in the future.

3 Discussion and Outlook

As a business function, procurement has been extremely successful during the last decades. In almost all industries, it has gained substantially in influence, professionalization, and organizational status. This trend, however, will not necessarily continue. The advent of new technologies and the digital transformation of operations and supply chain management will have profound implications for how firms organize their provision with external resources. The key topics of the future—innovation, sustainability, and resilience—provide great opportunities for procurement to support the competitive advantage of firms. But to seize these opportunities, procurement will have to shift its focus and change its mindset.

From the discussion with the executives, it can be seen that the perception of the value contribution of the purchasing function—which in the past was primarily to save costs—is now primarily to secure supply and to build sustainable and resilient supply chains. One reason is that companies increasingly want to prepare for disruptions caused by major unexpected events (Taleb, 2007) as recently demonstrated by the global COVID-19 pandemic. Among other things, these events led to massive disruptions in supply chains and in demand, shortages, or supplier failure (Bode & Macdonald, 2017).

The procurement organizations of the future will be characterized by a high level of flexibility to adapt to a fast and continuously changing environment. Furthermore, as the speed of procurement processes increases, decisions need to be made faster resulting in a high level of responsibility and autonomy of the employees. The trend toward automating operational processes will shift the focus from operational tasks to value creation in strategic tasks. Consequently, the responsibilities and tasks of employees in procurement become more complex, increasing the appeal of procurement for high-skilled employees. Communication skills, IT knowledge, openness toward changes, and the willingness to take responsibility become crucial for procurement practitioners, while their tasks become more diverse, ranging from applying process mining to track performance to monitoring supplier activities via interfirm cloud solutions and enabling groundbreaking innovations by closely cooperating with suppliers.

On the basis of our findings and related recent studies, the successful management and collaboration with suppliers will remain a key task of procurement functions. Due to the rising environmental and social responsibility awareness, consumers are demanding more transparency in the supply chains and even show a higher intention to buy when companies are disclosing their supplier monitoring activities (Duan et al., 2021). Further, a lack of visibility into supply chains and suppliers involved in the production process (tier 1, tier 2, tier 3 to raw material suppliers) has led to disruptions and increased risks at many companies during the recent and ongoing COVID-19 pandemic. The need for transparency about the details of the supply chain, its dependencies, and companies involved at every step, from the origin of goods to the finished product, has become evident and will become an even higher priority of procurement in the future. However, efforts to increase the visibility into the supply chain necessarily involve the respective supplier. Additionally, suppliers should also be considered when digitally transforming the procurement function, as many relevant processes are cross-company spanning and a one-sided digitalization and automatization usually does not exploit their full potential.

Management Perspective on the Future of Procurement

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> It's tough to make predictions, especially about the future![1]

The latest COVID-19 pandemic has shown how fast "black swan" events[2] can change the world and make previous predictions obsolete. The coronavirus is the latest catastrophe impacting humankind with its globally connected economy. The breakout of COVID-19 in China has shown how fragile global supply chains are and how severe the impact can be for the availability of goods across the world. Panic buying from hygiene articles to nonperishable food combined with a lockdown of production sites (entire regions got closed[3]) are only a few examples how fast supply chains got disrupted.

To mitigate risks the importance of the role of procurement as one core element of every supply chain[4] got into the spotlight of every company. Providing alternative products (and suppliers) was within weeks on the top of the CEO agenda during the pandemic. Procurement had to minimize the risks of running out of supplies in the warehouses to avoid a stop of production and got new tasks to source new products fast, like personal protective equipment (e.g., face masks) or disinfectants for the workforce.

(continued)

[1]This saying has been credited to Winston Churchill, Mark Twain, Niels Bohr, and others.

[2]Taleb (2007).

[3]First lockdown across Hubei province on January 23, 2020 (https://www.bbc.com/news/world-asia-china-51217455).

[4]Supply chain can be defined in a simplified way as plan, source (procure), make, and deliver, which is aligned with the SCOR model, which includes the return and enable process steps (Supply Chain Council 2012).

Managing risks is not a new priority for procurement. The 9/11 attack (2001), the tsunami in the Indian Ocean (2004), the financial crisis (2008), the eruption of the volcano Eyjafjallajökull (2010), and the catastrophe in Fukushima (2011) are examples, where procurement had to mitigate the risk to secure the needed supplies for the business. Managing supply chain disruptions and finding alternative products fast are part of the daily business of most procurement functions today.

The role of procurement has always gone beyond managing risks or mere cost cutting. After the empirical investigation of the status quo in the latest procurement profession survey with 817 respondents (key insights are reported in the following chapter), we analyzed the question of how procurement will change in the next few years. Five trends can summarize the current tendencies and allow a prediction on the future of procurement.

1. **Supplier Innovations**
   Procurement is evolving from a back-office to a value-generating front-office function supporting the business in the planning process of new products by leveraging supplier innovations. With approx. 65% of all company innovations sourced externally,[5] procurement is in the position to accelerate supplier-enabled innovations by leveraging suppliers' knowledge and capabilities. Procurement has potentially the deepest insights of supplier markets and access to information on available innovations. In some industries a close collaboration and innovation process with suppliers exists already today, like for automotive to develop new battery technology or high-tech to manufacture smartphones. New business models and innovations are key for the success of companies. Procurement can leverage their insights to find new suppliers or to find innovations to either improve an existing product or provide new manufacturing ideas, for example, Apple was doing it in 2007 for the introduction of the Gorilla Glass from Corning[6] for iPhones.
2. **Sustainability**
   The importance of environmental, social, and governance (ESG) has significantly grown and led to increased societal awareness, heightened investor pressure, and involvement of a wide range of regulators from all impacted areas. Subsequently, regulatory requirements have increased and will increase even more with an escalated complexity driven by regional and topic variety. Companies need a structured governance to ensure regulatory compliance across all ESG factors and in all regions.

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[5] BCG Procurement Practice Area project experience.

[6] https://www.corning.com/gorillaglass/worldwide/en.html

Owning relationships with suppliers, procurement has a unique position to boost company's social impact efforts and establish sustainable supply networks to achieve defined ESG goals, for example, 40% more bottles of Persil washing liquid can fit a pallet due to optimized bottle design; additionally, 30% less plastic is required.

3. **Autonomous Source-to-Pay Processes**
   A wide range of procurement tasks can be automated in the future leveraging AI-enabled systems. Connected devices and predictive maintenance allow a high degree of automation to indicate when a service is needed, or a replacement spare part must be ordered to secure a seamless runtime of machines. The same is applicable for standard purchases which are no longer needed to search in different catalogs. Also, negotiations might be supported by bots to find the price for the demand needed. Strategic and value-adding activities might stay limited on the automation potential but can get supported by analytics to find the best suppliers or products, for example, Amazon is suggesting AI-based product recommendations based on customer experience data.
4. **Resilient Supply Chains**
   In the world of growing uncertainty and complex global supply chains, procurement can help companies identify potential risks in the supply chain and suggest levers to apply to reduce specific risk exposure. The rapid change of production of breweries or chemical companies to produce disinfectant liquids is only one example of reacting fast and providing goods that are in demand.
5. **New Skills and Capabilities for Procurement in the Future**
   Increasing leverage of technology (data flows, AI, and interconnectivity) in combination with proven optimization levers will change the future procurement function—leading to a reduction of operational activities and associated costs. An increased focus of talents on strategic work and value-adding decision support for the business will increase the requirements for talents to drive category management, provide supplier innovations, mitigate risks, and work with highly automated systems. An augmented working model leveraging AI capabilities to benefit from more market and supplier data insights will define the roles for future procurement talents. New skills and job descriptions might occur to program AI, scout innovations, collaborate with business partners, analyze carbon footprint, or innovate distribution channels.

New, disruptive technologies can be used to automate a wide range of operational and, in some cases, tactical tasks in purchasing. Procurement will therefore increasingly have to be measured by the value contribution to achieve the strategic corporate goals. Strategic tasks such as driving supplier

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innovations, sustainability in supply chains and risk management are becoming more important to generate value for the business. The importance of procurement might continue to increase in the future and the CPO will have a leadership role in (or very close to) the board of directors. The CPO could be responsible for an expanded business area with a higher priority for the company and perhaps in the future be referred to as Chief Value Officer, Chief Collaboration Officer, or, because of his central role in the implementation of stakeholder and sustainability-oriented goals, Chief Purpose Officer.

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Agility in Supply Chain Planning and Execution

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1 Introduction and Literature Review

Variability comes in different forms. Some variability is very predictable, so much so that can be approximately considered deterministic. Other variability is not perfectly predictable, but can be quantified, measured, and described by probability distributions. Finally, there is variability that cannot be predicted or quantified *a priori*. This was described by some authors as early as the first half of the twentieth century. Walter A. Shewhart (1931) originally used the terms *chance cause* and *assignable cause* of variation to refer to the two latter kinds of variability. Similarly, Deming (1975) coined the term *special cause* of variation to describe variation caused by events that modified what is "natural" variation. Keynes (1921) talked about three kinds of probability: frequency probability; subjective or Bayesian probability; and events lying outside the possibility of any description in terms of probability (special causes). Knight (1921) differentiates between risk, "the possibility of alternative outcomes whose probabilities are capable of measurement" and uncertainty, "the possibility of alternative outcome whose probabilities are not capable of measurement."

The managerial and supply chain design implications of these different kinds of variability are significant. Among the first authors to spell out how supply chains should be segmented to respond to different kinds of variability was Fisher (1997). In his seminal framework, low variability should be addressed with efficient supply chains, while high variability with responsive supply chains. For the fashion segment of the apparel industry, Hammond and Kelly (1991) were among the first authors to argue that quick response should be the norm. However, for "chance" in the Shewhart sense, or "natural" variation in the Deming sense, Iyer and Bergen

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(1997) and Kraiselburd et al. (2011) show that, even in high variability scenarios, when retailer margins are lower than manufacturer's or when retailers can except (costly) effort to affect demand, quick response can be detrimental to the manufacturers that are not vertically integrated. Caro and Martínez-de-Albéniz (2015) describe the fast fashion approach, which is, in many ways, an evolution of the early quick response idea. As predicted by Fisher, Inditex, a leading, vertically integrated practitioner of the fast fashion concept (Ghemawat and Nueno Iniesta 2003), segments its supply chain, using an *efficient supply chain* with distant but cheap suppliers for their low variability items, and a *responsive supply chain* with close, flexible, and fast (but more expensive) suppliers for its high variability items.

Beyond efficient vs. responsive types of supply chains, with more and more sources of data and methods to process such data such as advanced analytics, artificial intelligence, and machine learning, several companies are going toward more and more automation in their supply chains. This has been advocated by top consultants and is successfully being implemented by industry leaders. Champagne et al. (2015) argue that automation can achieve faster decision-making, which could potentially make automation advantageous for responsive supply chains. Beyond responsiveness, Felix et al. (2018) argue that automation can also reduce human errors and biases and, consequently, improve supply chain performance. This is important because such human errors and biases have the potential to have devastating effects in interconnected supply chains. For example, Sterman (1989) and Lee et al. (1997) describe how order variability can be amplified when it travels upstream in a supply chain, a phenomenon called "the bullwhip effect." If this happens, upstream suppliers would be facing extremely difficult and costly to solve variability that was, in a way, "created" by this amplification. To make matters worse, this need not be limited to physical flows: Serrano et al. (2018) show that this phenomenon could also happen to financial flows along the supply chain. Even though this variability amplification can be caused by structural characteristics of certain supply chains, as pointed out by Sterman (1989) and Lee et al. (1997), behavioral issues tend to exacerbate the problem, as discussed by Croson and Donohue (2006). Automation can clearly help mitigate this problem. For example, when playing the famous "beer game," a game used in MBA and engineering classrooms around the word to illustrate the bullwhip effect, it is well known that simple algorithms (such as just ordering lot for lot) can avoid the bullwhip altogether and greatly outperform human players.

There is, however, a catch: automation can only help address "natural" causes of variation (in the Deming sense), or "risk" (in the Knight terminology). "Special" causes of variation (as defined by Deming) or "uncertainty" (in the Knight sense) are a complete different mater: because, in a sense, each event is unique, human intervention is key. This necessity of thoughtful human involvement is at the heart of Deming's (1993) "system of profound knowledge." But this point predates Deming, and by more than 70 years! In fact, Knight's (1921) main argument was that, because of competition, profits tend to zero under "natural" variability or, as he called it, "risk." It is human intervention when facing "special" causes of variation, or, in his terminology, "uncertainty," what can make the difference: "When probabilities are known, adverse outcomes may be insured against. Uncertainty is handled by judgment, an unequally distributed ability. The successful entrepreneur is one who has the sound judgment (. . .). The recompense for this talent is profit." Clearly, as Ebel et al. (2015) argue, companies can profit significantly from properly managing risk and uncertainty. But it is not just short-term profits that are at stake. Company valuations can be severely affected long term after a supply chain event is unsuccessfully managed (Hendricks and Singhal 2009).

A lot has been written about how to manage low variability supply chains, and supply chains exposed to risk or natural causes of variability. In academia, this is so, perhaps, because the first two kinds of problems can be more easily modeled using mathematics (either of the deterministic or stochastic kinds). The current events surrounding the COVID-19 pandemic have made practitioners and academics acutely aware of the capital importance for business and even our daily lives of dealing with the remaining type of variability, i.e., uncertainty or variability caused by special events. However, to date, a lot less has been published on this topic. Clearly, the usual mathematical tools of the academic trade can help. However, when facing this type of "one of a kind" yet not necessarily infrequent events, flexibility, automation, and advanced analytics, while useful, are not enough. Complementing this, the right "early warning" and quick reaction management system can make all the difference. This system can go by many names; in this chapter we will call it "agility in supply chain planning and execution." The remainder of this chapter will discuss how successful companies put together agile planning systems, and how this can help them profitably address small and large uncertain events to outsmart the competition, gain an edge, and even thrive in adverse circumstances.

2 Agility in Supply Chain Planning

The terms "agile" and "agility" have gained popularity in the professional literature and vernacular over the last decade. Although "agile supply chains" or "agile supply chain management" may refer to many different or nuanced concepts, in order to keep the scope of this article manageable to the reader, we will center on the concept definition that is borrowed from the "agile IT" domain. Conceptually, agile changes how we think of a decision-making process: from a "waterfall" method (i.e., first one plans what needs to be done, aiming at a perfected forecasting of variables and conditions, and then one executes the plan with hopefully little deviation from it) to an iterative method, where one recognizes that some variables might not be entirely knowable when a project is initiated, and, as a result, shorter plan-execution steps are made, so that better decisions can be taken once more visibility into variables can be established (see Fig. 1).

This methodology is commonplace in IT these days but also in areas such as R & D and innovation. The relevance of such change can't be understated in supply chains. Historically, for example, there was a huge reliance in forecasting techniques to define what and how products should be produced. Although there is meaningful value in perfecting forecasting techniques (e.g., machine learning, coupled with

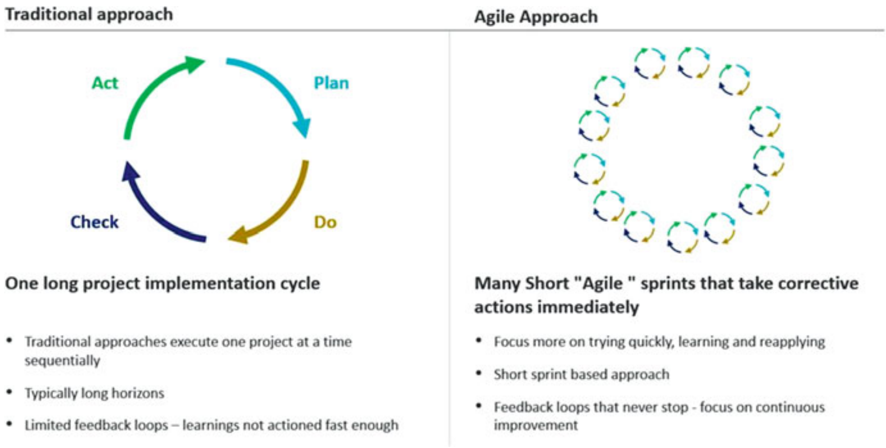

Fig. 1 Agile as a connected set of short PDCA loops vs. the traditional approach in supply chain planning

more data source availability, has been a recent source of material improvements in the space), the reality is that (1) for most products there is an irreducible core forecast inaccuracy even in best-in-class planning (i.e., it is rarely possible to improve MAPEs beyond approx. 15%); (2) there are products which, due to the nature of their demand, are substantially less forecastable (e.g., highly promotional items); and (3) unknowable events like COVID-19 can't be predicted and, if considered, would move accuracy well below what is theoretically possible considering "normal" variability. In such cases, on top of initially doing an appropriate forecast, companies should quickly iterate on how actual demand is evolving vs. the initial forecast, and quickly replan whenever deviations are material (within the constraints of such supply chain). This agile re-planning appropriately reorients the supply chain with material impact on service levels, inventories, and costs.

A global consumer goods company with dozens of distribution centers and plants and thousands of SKUs was experiencing a severe service level meltdown in its ability to serve customers—case fill rates had dropped significantly, in large part due to an increase in SKU and channel complexity in recent years (new SKUs, new channels, etc.). With a real limit in inventory days due to shelf-life issues and warehousing capacity, fixing the problem was difficult, and this was impacting commercial relationships. In order to regain control of its supply chain, the company created a four-layer agile planning process: the typical yearly process and quarter reviews, the traditional S & OP process, and two additional "fast layers": a weekly S & OP-like cross-functional decision-making process to replan against core deviations from plan, and a daily re-planning and load reallocation process based on instantaneous consumption in their DCs. With that, they were able to bring service levels up to 95%+ in 6 months. To properly measure the effect of these agile ways of working, the company kept, as a reference, control groups for the different processes, so effects can be seen beyond a "before and after" comparison.

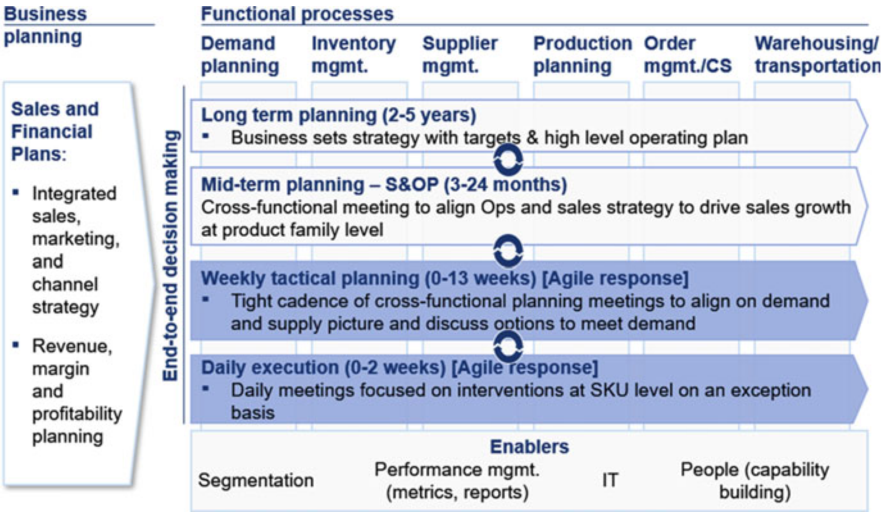

Fig. 2 Interaction of weekly and daily agile response layers with overall supply chain planning (highlighted in blue)

Figure 2 shows the interaction of the weekly and daily layers of agile response with the traditional S & OP processes. In large part, the improvement came from "chasing demand" vs. having to be perfect at forecasting in dozens of DCs and thousands of SKUs. The results in this example were remarkable but, luckily, can be replicated by others if the right elements of agile supply chain planning are put in place. In the remaining of the chapter, we will describe these elements with an eye on practical applications and adjustments required to make this work in other settings.

3 Core Elements of Agile Supply Chain Planning

Superior agile supply chain planning processes have some core characteristics:

Weekly and Daily Agile Decision-Making Forums, Cross-Functional in Nature Shrinking decision-making from monthly or bimonthly cycles to weekly and daily, with the appropriate adjustments on which time horizon of planning is being affected. In practice, on top of setting, as usual, detailed S & OP horizons to 3 months out (with less detailed, aggregated planning spanning longer periods, usually around 12 months), this requires weekly re-planning that can affect more heavily weeks 1–12 and daily adjustments for the next days/1 week out. This recipe is a direction instead of a prescription—depending on production and transportation lead times, customers, overall production, and distribution footprint; some of these parameters will change. Regardless of specific horizons, the important part is moving from acting as if the original S & OP plan was deterministic, to recognizing its probabilistic nature and handling deviations in a quick, iterative, and cross-functional manner. Cross-functional participation is also crucial (i.e., commercial teams, operations teams, finance), as these forums should drive actions that are agreed by the parties to be summarily executed and not constantly renegotiated (see Fig. 2).

Digital Fact Base One of the biggest hurdles for becoming agile in supply chains is the lack of an appropriate fact base for quick decisions. In addition, it is also easy for planners to be overwhelmed by the sheer amount of data available, and face difficulties to parse out what matters for these forums. In order to make agile decisions without overburdening the organization with endless meetings, standard digital dashboards focused on exceptions (i.e., deviations from plan that are material) to be discussed are critical. Simple technologies including data visualization software programs allow easy processing and visualization of meaningful amounts of data, with easy drill-downs that enable root-cause identification. Another important point to notice is that the core information that feeds those forums is typically the one most easily available in typical ERP implementations—supply chain data around orders, plans, inventories, etc. are typically very available, as they are used for invoicing orders. One can always sophisticate these systems even further with more sources of information, but a meaningful starting point can be achieved by leveraging available ERP information. Finally, another point that is crucial is that the information should be displayed in a way that helps the problem-solving of issues in a standard format: the sequence of dashboards should follow the sequence of answers required to secure appropriate decisions to enable service/inventory/costs to be optimized. Some companies at the forefront of this process provide additional analytics and system-based recommended adjustments—which are helpful and might save time, but are not precondition to the adoption of agile.

Visibility and Transparency In order to secure the appropriate discussion and decision-making, the abovementioned information must be available for all participants in the same manner. Again, currently available technology helps achieve this goal in a consistent manner—all members should receive the same reports or, at least, reports based on the same information and consistent assumptions. Companies in the forefront of this process recognize that a planner and a sales VP might need different cuts of the information, and as a result they provide this level of customization, aggregation, and analysis, as long as the drill-down and different dashboards are available and show the same core data.

Forward- and Backward-Looking Decision-Making Another core element of ensuring agility in the supply chain is, obviously, to take forward-looking actions that prevent any supply chain issues taking place (e.g., make sure inventory health is achieved across the portfolio through optimal production decisions that balance demand/supply). However, making sure the issues of the past do not repeat themselves is equally important. Continuous tracking of root causes when they can be found (using the visibility and transparency tools mentioned earlier) and instituting action tracking to address those root causes as part of the weekly/daily agile cadence will ensure adherence to forward-looking supply-demand plans.

4 Agility in the Times of COVID-19

The still ongoing COVID-19 crisis created one of the biggest levels of uncertainty and volatility that companies (and society at large) had to deal with in modern times. When the nature of the pandemic became more clear, and lockdowns more commonplace, demand and supply simultaneously moved widely in sometimes opposing directions. On the consumer's side, demand for some products increased widely, like, expectedly, house cleaning and food products for in-house consumption, but also sometimes in unexpected ways, e.g., the sudden spike in toilet paper purchases early in the crisis. At the same time, demand for other products decreased dramatically, like products oriented to food service, hotels, and restaurants (all of which were heavily affected by lockdowns), but also, demand decreases had cascading, indirect effects, such as a decrease in tourism and business travelling creating a decrease in oil consumption. Simultaneously, several industries faced multiple supplier disruptions, and increased lead times given by temporary closing of borders or increased clearance times at customs, rerouting of entry points, etc. Clearly, the widespread and sudden nature of all these changes created a "perfect storm" of sorts for supply chain professionals. Luckily for some, the same elements of agile described in the previous section were appropriate in this scenario—quick, heavy iteration of decision-making based on concrete facts of end-to-end supply chain demand and supply, many times spanning across the entire value chain, at a daily level, cross-functionally, and many times involving all echelons of the organization. Because of this, companies that had either gone through the effort of implementing these agile supply chain principles, or that did so in record time were able to react appropriately and even gain a competitive advantage with respect to their more traditional hierarchical planning-minded counterparts.

The nuance between the traditional and agile ways of working can be better illustrated by contrasting two North American companies in the fast-moving consumer goods that faced COVID-19 constraints. For confidentiality reasons, we will call them Company A and Company B. At the onset of COVID-19, both companies had well-performing S & OP processes. Although Company A already had a cadence of weekly agile meetings, with reasonable visibility of its core supply chain parameters (although not fully digital), Company B did not have a weekly cadence, albeit with a series of digital dashboards that different managers used individually in their day-to-day. When the pandemic hit, Company A quickly organized a daily iterative process and invested in building a single end-to-end visibility dashboard to be used by all decision-makers. The daily cycle started with operational and commercial teams meeting to solve the crucial imbalances and questions, raising areas of risk and articulating the list of must-haves to be executed in the day/rolling week. After this meetings, two sequential escalation meetings happened (up to the CEO/CFO as needed) to ensure all key points were decided jointly, without the need of multiple side meetings or relitigation of actions. Company B, in contrast, kept its monthly cadence and within-week meetings and tried to sort its issues through quick communication and action planning. However, the within-week meetings were not cross-functional in nature, and each team was operating in a silo assuming that decisions they were taking were optimizing the overall supply-demand imbalances in the company. In reality, without a cross-functional agile daily/weekly alignment forum, the gaps between demand and supply were growing wider. Over a 6-month period, the difference in performance would be noticeable: although both companies had a surge in demand and both companies had capacity constraints, Company A was not only more able to manage service and solve bottlenecks, it could also take drastic actions like reducing its SKU portfolio to increase its overall availability without customer satisfaction drop. On the other end, Company B, at the end of 6 months, was still struggling to really understand how to address service disruptions with clients, manage allocation processes, and understand the real source of capacity constraints and service cuts to its main customers.

It was not a matter of how intense their work was (both companies had high intensity), but rather how a different process enabled superior, integrated, decision-making in a faster way by following the agile logic.

5 The Way Forward

Agile planning is here to stay. It is a natural evolution of old-time traditional processes like S & OP, and now, by being enabled by digital, it can be truly iterative, more precise, and less taxing on the organization.

As companies adopt it, investing in digitalizing supply chain processes to support agility is becoming a no-regrets move. First of all, new digital technology can help in the traditional supply chain planning roles more related to "normal variation" such as forecasting, master production scheduling, etc., automating more and more decisions and allowing for ever more sophisticated analysis. For example, as machines become better than humans to detect trends (as in machine-learning forecasting), it might allow even faster and potentially automated decision-making. Given that in many supply chains the supply side is more stable, deterministic (because upstream demand is basically set once end demand is realized, suppliers often pool demand across many clients, etc), and the demand side is more variable, probabilistic, once the end demand is appropriately understood without human intervention, managing the rest of the supply chain becomes substantially simplified. In one case, ML-enabled forecasting allowed a company to drive 14pp of MAPE vs. human-based/statistical-based forecasting—improvements of this nature, coupled with more availability in data and visibility, are likely to become the norm and enable process simplification and better efficiencies across the supply chain. Such improved forecasting can be combined with state-of-the-art optimization software for automated decisions allowing for significant gains with respect to manual, human decision-based processes (a good example is Ferreira et al. 2016).

At the same time, when things turn out different from what was planned/calculated, digital technology can facilitate the implementation of agile decision-making systems by providing better, easier to visualize reports, setting alarms that define exceptions based on clear rules, etc. Many off-the-shelf systems are becoming available, and companies have created analytics hubs that can properly create the digital enabling mechanisms for agile planning. The combination of an automated decision-making system for "normal variation" with an early detection system for quick visualization of events that deviate from such normality, and an agile decision-making and execution system can be extremely powerful and is greatly enhanced by the smart deployment of digital technology.

After achieving a plateau of development with the maturity of S & OP (and, to an extent, IBP), properly combined agile and digital can provide the bedrock for a next generation of improvements in the field. Beyond its impact on adopting companie's performances, we believe this is good news for supply chain practitioners. Even though the number of jobs devoted to tasks that can be automated will decline in supply chain management and planning (just as everywhere else), agile supply chain planning processes cannot be replaced by machines. On the contrary, automation can only enhance the performance of humans by liberating the time they devote to menial, repetitive decisions, highlighting what requires human attention, and facilitating visualization and analysis. Thus, we see more and better rewarded supply chain planners in companies that have embraced agile planning. Such agile processes will thrive in highly uncertain, interconnected environments. The important thing is that, beyond the pandemic, in our interconnected world, large and small potentially disruptive, unplanned supply chain events are more and more common: for example, across industries, companies can now expect large supply chain disruptions lasting a month or longer to occur every 3.7 years on average. In this "new normal," we believe that agility, like digitalization, will become a no-regrets move for most companies.

Management Perspective on Supply Chain Agility Needs in the Next Decade

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As we look forward, supply chain agility and responsiveness is already becoming a critical topic. Agile supply chain planning and execution will be needed not only to react quickly to changing customer needs (e.g., shorter lead times, customized packaging) but also to quickly respond to sudden disruptions in the supply chain. In that respect, supply chain resilience and agility go hand in hand.

Three Areas of Importance

1. Real-time visibility/tracking and digitization of the supply chain—Real-time visibility to enable real-time decision-making (e.g., rerouting products

(continued)

en route based on upcoming expected disruptions to ensure service levels), powered by big data analytics, single-threaded sources of data, and also IoT/tracking devices.

2. Advanced analytics for supply chain planning—Advanced analytics can help in the traditional supply chain planning roles such as forecasting, master production scheduling, etc. automating more and more decisions and allowing for ever more sophisticated analysis. For example, as machines become better than humans to detect trends (as in machine-learning forecasting), it might allow even faster and potentially automated decision-making. Given that, in many supply chains, the supply side is more stable, deterministic, and the demand side is more variable, probabilistic, once the demand is appropriately understood without human intervention, managing the rest of the supply chain becomes substantially simplified.
3. Change management—Supply chains are becoming more interconnected, bigger, and more complex. Cross-functionally aligning joint actions that balance both supply and demand gaps requires processes, systems, and leaders. Many times functional silos need to be dissolved to make joint aligned actions. Change management is central to adapting to the new "ways of working."

In summary, digital accelerators like real-time visibility and advanced analytics along with management infrastructure and change management are important.

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Risk-Driven Supply Chain Design: Options and Trade-Offs in Complex Environments

Marcus Thiell and Gordon Wilmsmeier

1 Introduction

Supply chain strategies develop in relation and as a response to their environment. Over the last couple of decades, the search for always greater efficiency was accompanied by the concept of agility. The advances of globalisation were to a significant part built on these pillars, as they benefitted from relative stable environments. Thus, globalisation was driven by a wide range of standardisation of supply chain structures and processes. The traditional concept of globalisation and the continued economic growth paradigm have come under scrutiny. As the world contends with greater volatility and uncertainties in the political, economic, environmental and social spheres and seeks a 'new' equilibrium in future sustainable development, supply chain strategies need to adjust. This complex environment bears great chances for success, but also failure given a greater probability and impacts of risks.

2 A Changing Context and Environment

The World Economic Forum (WEF) (2021) refers to the current environment as one of 'fractured futures'. The mentioned increasing volatile and complex environment may best be exemplified referring to the impact of the Covid-19 pandemic on risk

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perception. According to the 'Global Risks Report 2020', infectious disease was ranked above average in terms of impact, but as the third most unlikely global risk to happen (WEF, 2019). However, in the most recent report (WEF, 2021), infectious disease now ranks as the fourth most likely risk and the one with the highest impact. This change of risk perception reminds of other triggers of supply chain disruption like 9/11 in 2001, the financial crisis in 2007–2008 and the Japanese earthquake in 2011. The last two decades have consequently produced at least four of such events. Given such frequency, one might have expected that the likely occurrence of such disruptions forms an integral part of strategic supply chain planning.

However, despite growing complexities in our environment, supply chain strategies have so far always bounced back towards a mix of cost/efficiency and agility paradigms. Private cost continues to be the leading dimension. The Covid-19 pandemic has revealed the unpreparedness and fragility of supply chains and has triggered unprecedented and still incalculable economic and social effects. This is once again reminding us of already known limits of the traditional form of globalisation (cf. Goldin & Mariathasan, 2014). The relentless search for efficiency in supply chains resulted in a system of increased complexity, cost focus and in-transparency, and the Covid-19 crisis represented the impulse removing of the final brick causing the hollowed out *Global Supply Chain Jenga* tower to implode (Thiell & Wilmsmeier, 2020; cf. for the use of Jenga example, see Isenberg (2015)). Structural fragilities and dependencies became evident and should awake a general reassessment of supply chain structures and processes and their limitations of 'efficiency', 'agility' and even 'resilience' when applied in complex environments.

The, too long, idealised concept of globalisation has been and is continuing to be interrupted by the Covid-19 pandemic, not only by re-establishing physical borders but also by cutting global supply chains via political, or (often) unilateral, decisions, prioritising national interests over a global solidarity. Referring to *force majeure,* managerial decisions have been following similar pathways. These disruptions and threats of repetition created the following: (a) limiting equal access to markets, (b) fabricating an excessive vision of risk for business and society, (c) promoting excessive inventory variations and backlogs, (d) changing consumption pattern and (e) revealing quasi-monopolistic and monopsonic relationships along supply chains.

The world is at a crossroads, where climate change is increasingly affecting our economic activities, creating additional uncertainties. At the same time, there is a growing awareness on the limited capacities for preventive policy making and global governance, making our systems more vulnerable and exposed to volatility. Here volatility includes four dimensions: political, environmental, economic and social.

If we were to take the effects of the Covid-19 pandemic as an example for complex environments, until mid-2021, global supply chains were already effectively hit thrice:

First by the effects of the China lockdown, which revealed the significant dependencies on Chinese finished and intermediate products and components;

Second by the elimination of demand on the markets successively impacted by Covid-19 and going into shutdown. The results of these two effects demonstrated an artificially initiated divide in high demand increase (e.g. hoarding effects, health sector supplies) and substantial demand decrease (e.g. tourism, accessories, fashion).

Third by showing that ramp-up efforts to reach full utilisation of productive assets in a 'new normal' continue to be limited by uncertainties and recurrence of restrictions in different parts along the supply chains. Finally, the future economic knock-on effects through reduction of purchasing power, investment decision trade-offs (i.e. durable consumer goods) and a reorientation of consumerism (i.e. less quantity and diversity, a more local/national product and service geography) are still evolving.

The complexity of global supply chains and their lack of transparency and collaboration have led to little or no control over disruption causes and even less capability to trace the unfolding consequences and their underlying relationships, particularly in emerging economies (cf. Richter, 2011; Foroohar, 2014; Barbieri, 2016; Medhora, 2017). Shifting from globalisation idealism to national protectionist realism leaves emerging economies chasing shadows of the fallen *Global Supply Chain Jenga* tower (cf. Bloom, 2020; Thiell & Wilmsmeier, 2020).

This chapter discusses if and how to adapt or possibly restructure supply chain designs to the impulses set, risks observed and disruptions caused in complex environments. Given the dynamics of global supply chains in general, adaptation is not a new requirement for their design (Lee, 2004). What is new in the context of the Covid-19 pandemic is the magnitude and simultaneity of economy- and society-wide approaches in which also the (re-)actions of many other actors outside the direct economic system need to be considered, e.g. the role of public health, technological developments and geopolitical scenarios.

In light of more complex future environments with increased uncertainty and volatility might require designing less 'fragile', speak antifragile (Taleb, 2012), supply chains, resulting into structures with wider or even dynamic control limits, in particular looking for a re-enforcement of practices as a balanced set of different strategic options instead of the 'one-size-fits-all' solutions. Considering these developments, this chapter critically reflects on the validity of traditional cost, efficiency or agile dominant supply chain structures and proposes a framework that allows decision-makers to assess strategic design options and their trade-offs in complex environments.

3 Complexity and Risk in Supply Chain Design

This section discusses key concepts related to drive, anticipate, mitigate or respond to risks. Supply chain risk analysis has been discussed widely in literature. Christopher et al. (2003) define supply chain risk as any risk to the information, material and product flow from original suppliers to the delivery of the final product. Beyond this, numerous definitions of supply chain risks and risk management exist (Ritchie & Brindley, 2004), often with marginal differences. Supply chain risks can be categorised as supply, process, demand, intellectual property, behavioural, political/social security (Tang & Tomlin, 2008) and disruptive risks. Consequently, these risks can be separated into endogenous risks, which are caused by companies' activities along their supply chains, and exogenous risks that affect companies given their interaction with the external environment in which they operate (Faisal, 2009). The dimensions that make these risks different are unit of analysis, type of risk, likelihood, impact and frequency. While the definitions and categories of risks seem clear, the conversion towards consideration and implementation in supply chain design in practice has been limited in the past.

Industry and academic discussions on supply chain risk strategies frequently refer to agility, robustness or resilience (e.g. Elleuch et al., 2016), as most common contingency approaches. The authors argue that it is necessary to amplify the perspective by considering root causes of supply chain disruptions. Under pressure from disruptive events, most supply chains traditionally tend to adopt to even 'leaner' models, which often makes them more fragile and vulnerable (Chowdhury and Quaddus, 2016).

Research on the effect of exogenous supply chain disruptions on supply chain competitiveness started to develop more strongly after 9/11 (Sheffi, 2002; Hau & Wolfe, 2003). And past disruptive as well as the Covid-19 pandemic have been followed by a flood of studies on supply chain risk and management. Despite a growing body of research in this area, exogenous risk orientation in supply chain designs was found still to be limited given the experience effects on supply chains during the Covid-19 crisis. One reason for this can probably be explained by managers' attitudes towards risk and their belief in continued and 'unstoppable' growth, as well as efficiency and agility being a panacea for competitiveness. Such beliefs have widely (and knowingly) ignored actual possible vulnerability (Bostrom, 2019) and collapse (Bemdell, 2018) scenarios, which could expose the fragilities (Manheim, 2020) of current supply chain designs. Therefore, beyond the previously mentioned concepts, fragility as a main cause, adaptability and antifragility as main mitigation approaches are defined in the following.

Fragility is a result of context factors (external and internal) and managerial decisions of how to deal with them, specifically considering the collapse of the supply chain structure as a possible future event, as a scenario (Manheim, 2020). Vulnerability can be defined as a risk-increasing factor. Jüttner et al. (2003) define vulnerability as 'the propensity of risk sources and risk drivers to outweigh risk mitigating strategies, thus causing adverse supply chain consequences affecting the supply chain's ability to effectively serve the end customer market'. Thus, while vulnerability measures loss in case of occurrence, fragility measures the occurrence's probability. Given this relation, addressing the vulnerability of supply chains is an 'end-of-pipe' approach compared to addressing such system's fragility. Effectively, the knock-on effects of the recent pandemic met highly fragile and ultimately vulnerable supply chains, which were predominantly characterised by unpreparedness, complexity, lack of leadership and supply chain skills, lack of collaboration, lack of transparency and visibility and cost focus. Following this logic, the supply chain designs were too fragile to deliver adequate performance against the defined value propositions in the situational context of the Covid-19 pandemic.

Thus, recent experiences of supply chain disruptions have shown that neither the most ‘responsive’ nor the most ‘efficient’ supply chain design (Fisher, 1997) has insured effectiveness and allowed organisations to maintain their performance level and competitiveness. The multi-disruptive impulse tested system boundaries (robustness) and effectiveness of supply chains’ internal control limits (resilience). The paradigm of robustness relates to supply chain’s ability to maintain its planned performance following a disruption event (Nair & Vidal, 2011; Simchi-Levi et al., 2018). We differentiate between ‘resilience’ and ‘robustness’ as both terms are often used interchangeably despite referring to distinct concepts in the supply chain context. Robustness refers to sturdiness and a system’s ability to respond to errors while continuing to function. Resilience in difference is defined as the system’s ability to recover its original state or move to a new, more desirable state after having absorbed disruption effects (Christopher & Peck, 2004; Spiegler et al., 2012; Hosseini et al., 2019). Since the ways the disruptions occurred and propagated along the supply chains during the Covid-19 pandemic were non-obvious, but largely dependent on the architecture and the interdependences between supply chain elements, the limits on maintaining performance and competitiveness of these two paradigms emerged.

Consequently, agility became a popular and widely used term to describe requirements for supply chains to respond to the disruptions triggered from the Covid-19 pandemic. However, agility in supply chains traditionally relates to its capability to react quickly to changes and uncertainties in demand and supply (Lee, 2002, 2004; Eckstein et al., 2015), sometimes even limited to changes of consumer expectations, but seldom related to be triggered by external supply chain risks. Resilience and agility implicitly carry the notion of flexibility in their definitions, but do not consider that the state after a disruption can be different from the original state prior to the disruption.

Following the nomenclature of Lee (2004), supply chains might be required to assess their structures under a broader view of their ‘adaptability’, including a stronger focus on strategic options and design effectiveness. Adaptability consequently sets the ‘control limits’ with a ‘wider range’ or on a different attribute level with the same range and allows the system to define new and different states after being disrupted (Christopher & Peck, 2004). These limits will then also define the system’s capability in which it can adjust under an agility paradigm.

In the context of complex environments, it is important that an adaptive supply chain can change its state as a response during the occurrence of a disruption; this response will not be defined in the original design of the supply chain. Consequently, an adaptive supply chain will create resilience and robustness in different disruption scenarios. However, the concept of adaptability does not necessarily be sufficient, if environments are volatile. Taleb (2012) proposes the concept of antifragility as such supply chain would be set to not only resist to and adapt after disruptions but also to improve to be better prepared in the future.

Fig. 1 Balancing paradigms in supply chain strategies in complex environments. Source: Authors

What is emerging is that future supply chains will require integration where different paradigms will coexist within the same supply chain (see Fig. 1). Such integration will require combinations creating multidimensional dynamic boundaries between different supply chain strategies. Here trade-offs will emerge where the combinations neither result in the lowest cost nor most resilient or most agile supply chains. Such circumstances set the stage for discussing alternative supply chain designs.

4 Conceptual and Methodological Framework

4.1 Concept

The authors propose a conceptual framework for decision-makers to define options and trade-offs for supply chain designs. The conceptual framework questions predominant designs by considering supply chain fragility and its underlying causes.

In the past, a widespread efficiency and private cost focus guided managerial practices including the adoption of lean and just-in-time practices, outsourcing, moving to offshoring (in-house and outsourcing) and reduction of the supplier base. Reviewing the traditional supply chain literature, the authors identify the following ten dimensions with opposing options for supply chain designs (see Table 1).

The following paragraphs explain each of the dimensions and give examples:

(D1) **Geographic proximity** refers to the distance between the actors in the supply chain. In comparison to a local or domestic network, a global network raises the heterogeneity of supply chain characteristics and consequently also increases supply chain complexity as well as its fragility (Levy, 1995). The piracy-related disruptions off the coast of Somalia in 2007–2012 provide an example in this field, having exposed supply chains to challenges not prevalent in many domestic regions. Under the term of 'nearshoring', the questions of the optimal geographic proximity became particularly relevant in the course of the Covid-19 crisis in 2020–2021,

Table 1 Supply chain design: options

Dimension	Likely impact on SC fragility (ceteris paribus)	Opposed options	Example
D1) Geographic proximity	Increasing geographic distance leads to higher fragility	'Local sourcing' ⇔ 'Global sourcing'	Somalia piracy (2007–2012)
D2) Collaboration	Decreasing collaboration leads to higher fragility	'Partnership' ⇔ 'Arm's length'	Aisin/Toyota valve supply disruption (1997)
D3) Number of suppliers	Decreasing number of suppliers leads to higher fragility	'Multiple sourcing' ⇔ 'Single sourcing'	Japanese earthquake-tsunami-nuclear disaster (2011)
D4) Competitive priority focus	Increasing focus on cost (narrow definition of value) leads to higher fragility	'Value' ⇔ 'Cost'	Ecopetrol (2021)
D5) Degree of vertical integration	Decreasing vertical integration leads to higher fragility	'Insourcing' ⇔ 'Outsourcing'	Mattel toy recall (2007)
D6) Redundancy (volume)	Decreasing volume redundancy leads to higher fragility	'Buffered' ⇔ 'Lean'	Volcanic eruption in Iceland affecting production of BMW (2010)
D7) Risk management	Increasing focus on contingency capabilities leads to higher fragility	'Mitigation-based' ⇔ 'Contingency-based'	Covid-19 pandemic (2020)
D8) Information sharing	Decreasing information sharing leads to higher fragility	'Transparency' ⇔ 'Asymmetry'	Nokia and Ericsson chip supply from Philips in Albuquerque (2000)
D9) Intermediation	Increasing intermediation leads to higher fragility	'Integration' 'Fragmentation'	'Bullwhip effect'
D10) Redundancy (spatial)	Decreasing spatial redundancy leads to higher fragility	'Volume centralisation' ⇔ 'Volume dispersion'	Thailand floods (2011)

Source: Authors

considering that 'strategic supplies' like medical equipment should be produced in the direct proximity to the consumer markets.

(D2) **Collaboration** refers to the continuum of design options between 'arm's length' on the one hand and 'partnership' on the other hand. With increasing collaboration, supply chains are supposed to protect themselves better against disruptions by reducing opportunistic behaviour and pursuing joint approaches to plan and to execute supply chain operations with greater success than when acting isolated (Simatupang & Sridharan, 2002). The collaborative approach in which the disruption caused by the 1997 Aisin Seiki fire was solved in and by the Toyota supplier network demonstrates the power of partnership to reduce fragility: bringing in additional engineers, working overtime and sharing knowledge and other resources made it possible to reduce the expected downtime from several weeks to only 5 days (Nishiguchi & Beaudet, 1998).

(D3) With a decreasing **number of suppliers** per purchasing item, the dependency of the buyer increases. In the case of single/sole souring, the buyer places 'all eggs in one basket'. The case of the Japanese earthquake-tsunami-nuclear disaster in 2011 illustrates such case in which companies who relied on single sourcing approach considering 'low cost and high quality' experienced supply shortages, e.g. Ford had to stop taking orders for several models in the colour 'tuxedo black' that was provided by a supplier in Japan.

Such example also demonstrates that the ceteris paribus condition is crucial in the application of the conceptual framework. A general increase of fragility by focussing on one supplier can be partly compensated, e.g. by developing very strong relations including information sharing.

(D4) Guided by the **competitive priorities** of an organisation, a narrow value definition with a focus on cost increases the fragility of the supply chain. Cost-driven supply chains often improve productivity by reducing the amount and/or value of factors involved, but they may expose supply chains to higher risk of disruption. In 2020, the Colombian energy company Ecopetrol was also hit significantly by the pandemic crisis. Nonetheless, given its public-private nature and a wider value proposition, explicitly involving diverse stakeholder interests into its operations, it is concluded that Ecopetrol was better prepared to face the Covid-19 crisis than other actors in the market.

(D5) A **vertical integration** reduces supply chain fragility, considering that communication, control mechanisms and decision-making processes may work better under such condition than in a hollowed-out organisation with a high proportion of outsourcing. Tendencies towards 'insourcing', like the Apple chip plant in Munich, can in such context be interpreted as (re-)gaining control over operations previously outsourced. In a similar way, the public discussion about the diverse toy recalls of Mattel in 2007 evolved to a large extent around the use of lead paint in several toys (design problems responsible for a larger amount of toy recalls did not receive the same attention in media). While Mattel also had 'offshore in-house' operations, the disruption caused by the use of lead paint was occurring in its 'offshore outsourcing' operations.

(D6) Protecting a supply chain against disruptions with **volume redundancy** throughout its elements reduces supply chain fragility. Also addressed in the theory of constraints, inventory buffers prevent bottlenecks from running idle, avoiding a disruption of operations. In 2010, BMW experienced such disruption of its transatlantic make-to-order supply chain model from Europe to its plant in Spartanburg (USA) because of the volcanic eruption in Iceland that caused the closure of air space.

(D7) The reliance of an organisation to react quickly to a supply chain disruption, even under the idea of agility (Lee, 2004), may not be a sufficient **risk management** approach following a supply chain fragility perspective, given that such actions primarily address the consequences of a disruption. Instead, a risk management focussing on risk mitigation would address potential disruption causes and consequently increase the stability of a supply chain. The Covid-19 crisis revealed in many organisations and industries the lack of preparedness to deal with such disruption, and the contingency approaches even caused new disruptions resulting from cancelling contracts and shutting down operations (Thiell and Wilmsmeier, 2020).

(D8) Supply chains run on information; consequently, **information sharing** leads to transparency and reduces the fragility (Lee et al., 2000). Driven by performance improvements of information technologies and the reduction of their cost, the trend towards end-to-end supply chain visibility affects today's supply chains more and more. Nonetheless, confidentiality concerns, lack of trust or target-oriented use of information asymmetries may hinder organisations to create lower levels of fragility by means of increasing information sharing. However, in a supply chain that possesses visibility, a substitution of material flows by information flows becomes more likely. Nokia's fast and overall positive response to a fire in the semiconductor plant of Philips in Albuquerque (USA) in 2000 was also a result of the way how information about this disruption was shared within the organisation and its supply chain.

(D9) Complexity of supply chains augments with every new element added to it, consequently, with an expanding **intermediation** increases the fragmentation and, ceteris paribus, the fragility (Dominguez et al. 2015). A short supply chain, in terms of few vertical elements respectively multilayers, may require a lower coordination effort within the chain, because, as a tendency, it facilitates the communication and alignment between the actors. The bullwhip effect in supply chains illustrates the relation between the number of vertical actors and the magnification of variability in the supply chain (Lee et al., 1997). Bray and Mendelson (2012) show different real-world cases, e.g. Caterpillar on how the bullwhip effect impacted supply chains.

(D10) **Spatial redundancy** refers to the impact on fragility resulting from the level of centralising volumes, e.g. having suppliers for a specific product just in one particular location in the world. This type of supply chain fragility was observable in the context of the floods in Thailand in 2011, leading to supply shortages, e.g. for hard disk drives. On the one hand, a centralisation of volume in a region with cluster-like structures results in benefits, e.g. with respect to productivity and innovation. But on the other hand, from the perspective of supply chain fragility, a spatial redundancy of productive capacity in geographically dispersed regions will reduce the impact of a disruption in moments of natural disasters or turmoil.

For each of these dimensions (D), managers need to determine where to position their supply chain design along the axis between the two opposed options mentioned in Table 1. In this process, several aspects need to be taken into consideration:

- Given the diversity of products, material and markets, it is recommended to provide such design for each product/material category.
- Once committed to an option in one of the dimensions, the array of possible solutions in other dimensions delimit, indicating an interdependent relation between several dimensions; for example: a company focussing on single sourcing (D3) may also strive for higher levels of information sharing (D8).

- The feasibility of the supply chain design should be evaluated against the resources available for managing the system (e.g. IT and human resources) and the external context of an organisation (e.g. social, economic, environmental and political).

4.2 Decision Framework

The framework for a strategic assessment of supply chain design options asks decision-makers to define the importance of opposed options in each dimension on a five-point Likert scale (1 being of 'low importance' and 5 being of 'high importance'). While the use of such a Likert scale is inevitably arbitrary, we argue that it is nonetheless a useful first step for comparing the relations and trade-offs between supply chain design options on such aggregated planning level.

To exemplify the trade-offs, the authors differentiate between two extreme cases for one commodity supply chain in an organisation as a basis for the discussion on how to design the supply chain under fragility considerations (see Fig. 2). The greater the surface of the decagon in the cobweb chart, the lower the fragility of a supply chain design. This is represented in Case A, showing some aspects which Fisher (1997) referred to as elements of a 'responsive supply chain'. Case B shows a (traditional) cost-driven supply chain design, in terms of Fisher (1997) referring to several elements of an 'efficient supply chain':

- Case A: The 'non-fragile supply chain' is characterised by the following: 'Company X' has a local 'Supplier A' (D1) for its 'Category Δ', managing the relation as partnership with open book contracts and volume commitment (D2). Besides the positive business relation with 'Supplier A', 'Company X' also has a back-up 'Supplier B' who has a similar performance and counts with 20% of the purchasing volume (D3). The production facilities of the suppliers are geographically dispersed (D10). 'Company' X' follows a wider value definition, taking into account sustainability aspects and the interests of a diverse set of stakeholders

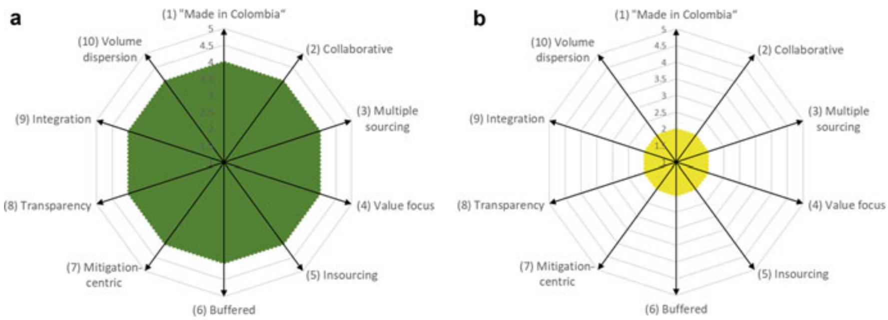

Fig. 2 Supply chain design: extreme cases (**a**) 'non-fragile supply chain design'. (**b**) 'fragile supply chain design'. Source: Authors

(D4), striving for a higher vertical integration by insourcing activities from suppliers back into the organisation (D5). To protect the supply chain elements from running idle, inventory buffers are integrated throughout the supply chain (D6). Risks are managed by focussing on the potential disruption causes (D7), and information is shared (D8) in the short supply chain (D9) in real time.

- Case B: The ‘fragile supply chain’ is characterised as follows: ‘Company Y’ has for its ‘Category Φ’ a ‘Supplier D’ located outside the country (D1). ‘Supplier D’ is the sole supplier (D3) for this category with its production facility accounting for 100% of ‘Company Y’s’ purchasing volume (D10). The relationship between ‘Company Y’ and ‘Supplier D’ is characterised by a power-based battle for margins (D2). ‘Company Y’ strives for profit maximisation (D4), using outsourcing as an approach to achieve lower cost (D5). A ‘zero inventory’ policy is part of ‘Company Y’s’ DNA (D6). Risks are managed by relying on the capabilities to react quickly and in flexible way at the moment a disruption occurs (D7). Information is in general classified as ‘confidential’ (8) in the long supply chain including many specialised intermediaries (D9).

Being aware that those two extreme cases in their pure form will hardly be prevalent in industry, the application of the framework makes differences visible, indicating that supply chains actually offer design options supporting the differentiation of an organisations in complex environments.

Organisations are in general part of several supply chains with different ‘design profiles’, leading to higher organisational complexity. Besides supporting the design of one supply chain, organisations are also well advised to review this heterogeneity of the diverse supply chain profiles following a resource-based perspective. Bundling resources to strengthen the management of certain supply chain profiles may be another trade-off supply chain managers should consider. The focus in such discussion is thus on a systemic response to complex environments rather than the assessment of just partial decision options.

4.3 Mini-Cases: Feasible Commodity Supply Chains (Colombia)

Initial tests of the decision framework in Colombia demonstrated that supply chain designs were traditionally focussing on efficiency aspects, tacitly accepting the inherent risk of resulting fragility.

In an assessment of feasible supply chain designs with a group of undergraduate students as well as a group of experienced managers in an executive education program, participants were asked for their proposal related to a future design based on a predetermined mini-case. Figures. 3 and 4 demonstrate the results of the two groups, applying reduced design options related to the question: ‘Considering a typical supply chain for commodities like car spare parts, which feasible supply chain design would you propose for the future (2025)?’

As demonstrated in examples above, both groups expressed a shift from fragile supply chains towards less fragile options. Both groups propose more information

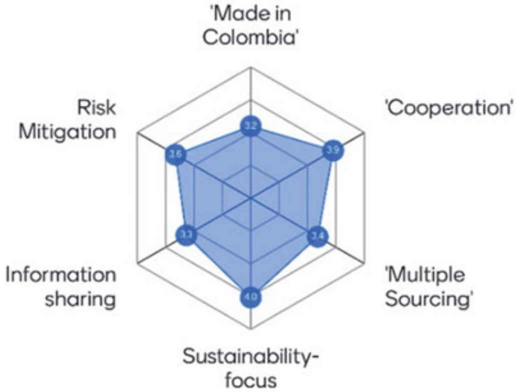

Fig. 3 Commodity supply chain design: executive education. Source: Authors

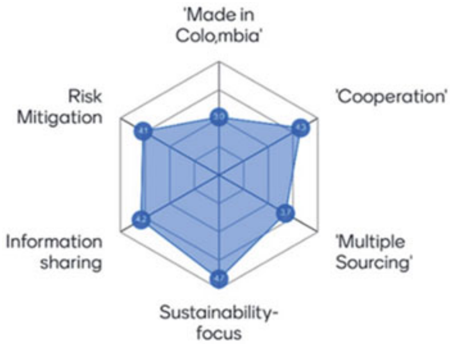

Fig. 4 Commodity supply chain design: undergraduate. Source: Authors

sharing, and more collaboration. Furthermore, the participants exhibited a tendency towards a more holistic value perspective, considering sustainability aspects and a stronger focus on risk mitigation instead of contingency approaches. Overall, the undergraduate group demonstrated a stronger desire towards less fragile designs in all dimensions.

Despite the motivation of changing supply chain designs, these initial experiments also identified specific impediments due to the Colombian context. Barriers were in particular identified with respect to the competitiveness of local industries in comparison with global supply chains, making the option ‘Made in Colombia’ less feasible.

Such results indicate that the decision of supply chain design will require the consideration of the specific context of the decision-maker and the relevant ecosystem, including factors like cognitive limitations or personal biases of the decision-makers as well as resource limitations and competitive priorities of the ecosystem.

Considering past globally significant supply chain disruptions like the ones caused by the financial crisis in 2008 or the Japanese earthquake in 2011, such context factors may also reveal that the actual implementation of changes may be restricted by an ‘inertia to change’, e.g. resulting from the following factors:

- Path dependence: our traditional and existing structures, resources, processes and business habits may limit the scope of actions, in particular when the effort and the outcome of change are uncertain.
- Definition of value and performance: we may still be significantly influenced by considering cost and profit as main optimisation criteria for our supply chain designs. But new designs should also consider a shift from cost-dominant to emphasising other characteristics and attributes, e.g. security of supply, time, quality, robustness, transparency, dependency levels, ecological footprints, social impact as well as changing stakeholder preferences in the course of time.
- Opportunity cost of change: changes may involve, at least temporarily, opportunity cost, interpreting change as an uncertain investment into the future. One may ask if companies are willing to obtain lower margins, if customers accept higher prices or how will stock markets react when there are 'profit warnings' reported by organisations.

The impulse of the financial crisis in 2008 and the Japanese earthquake in 2011 on the contemporary debate about supply chain designs was strong, but not strong enough to initiate significant changes away from cost- and efficiency-driven supply chain designs. The next years will show if the Covid-19 pandemic crisis will change our way of doing business or if the 'new reality' will be a clone of the 'old reality'.

5 Conclusions

Over the last two decades, supply chains were affected by many severe disruptions, and the 'lessons learnt' just seemed to have short time horizons of prevalence. Sometimes denoted as 'once-in-a-lifetime' events, this millennium showed us with 9/11 in 2001, the financial crisis in 2008, the Japanese earthquake-tsunami-nuclear disaster in 2011 and currently the Covid-19 pandemic crisis already four of such events. The consequences of complex environments on future supply chain designs are still unquantifiable, probably most likely underestimated and neither limited to, ripple, nor domino effects, but rather *multi-ball pinball game situations*. With a strategic planning time horizon of 5–10 years, organisations may be well advised to integrate the potential occurrence of a significant disruption into their plans and the supply chain design.

In this regard, this chapter reflected on possible supply chain design responses to current and future complexity and provides decision-makers with a framework for a strategic assessment of their supply chain design, considering their fragility in complex environments.

The capabilities to manage such complexity, fragility and risk have the potential to become key factors influencing the way supply chains are designed and managed in the future. Supply chain professionals will need to identify and interpret how complexity and fragility may jeopardise the perceived optimum of existing supply chain designs. The opportunity costs of maintaining and relying mostly on contingency approaches might become too high in the future.

Agility and resilience will remain important strategic options, particularly in the context of supply chains driven by private cost. However, the future will ask managers for a more holistic interpretation of value, in a first step internalising social costs and later satisfying the stakeholder expectations in terms of sustainability. This will require supply chain professionals to adapt a risk management culture that expands their response options in complex environments by determining the fragility trade-offs between contingency- and mitigation-oriented supply chain designs.

Management Perspective on Risk-Driven Supply Chain Design: Options and Trade-Offs in Complex Environments

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Well-designed product supply chains just like well-functioning international financial markets are based on the premise that success requires the efficient allocation of capital necessitating high levels of market visibility. That visibility should include the likelihood of certain negative or instability causing events occurring and their consequences for the supply chain. These occurrences, including climate- or health-related examples, or others caused by geo political events, are not rare, so why are they not quantified and factored into supply chain design? Clearly, some are but what happens when critical information or data is not available or is obscured because it cannot be quantified? This problem is relevant when you consider that supply chain practitioners are being asked to design or manage their global operations with large chunks of data missing. Following the logic of Thiell and Wilmsmeier's suggestions for redesigning supply chains as set out in this chapter leads to the question – how do we fill the information gap? They argue that supply chain practitioners are not correctly allocating capital when assessing future risk, because of either 'inertia to change' (in particular reliance on the traditional cost-based model), an inability to deal with an increasingly complex environment or a lack of understanding in how to assess risk and possible negative outcomes. The solution is a change to supply chain design. How can we get supply chain practitioners any time soon to sit down, redesign and plan based on different 'dimensions' beyond efficiency? This begs the question how does a useful academic thesis translate to change at the strategic and operational level? What steps might be taken by the academic community and private sector to find a solution?

It is obvious that some data or information deficiency comes into the 'too difficult' category and some 'too remote or unlikely'. Perhaps neither of these excuses should now be accepted if a general set of tools could be developed refined by location, industry and so on.

(continued)

Thiell and Wilmsmeier highlight methods for making choices through opposing options grouped under ten dimensions such as proximity (local vs. global) and collaboration (partnership vs. arm's length), all critical in the increasingly complex supply chain. However, if the global supply chain is susceptible to forces and events outside the supply chain manager's control, the real conundrum is how to quantify the risk associated with each to aid planning and thus investment. To redesign the supply chain requires evidence of the consequences of choices and risks taken. The insurance industry constantly refines its underwriting risk and models possible liabilities. While risks are well known when assessing insurance pricing for say car insurance (pre automation), it is less the case when assessing the effects of dramatic climate events or global viruses shutting borders. But the supply chain cannot wait to be forced to redesign based on its insurance costs or ultimately consumer rejection of its products on environmental grounds. There should be a strategic assessment of the options for redesign, the costs and benefits based on known or calculated risks.

A few years ago, F&L conducted a survey of its network by dividing the supply chain into its constituent actors and asking each actor how they ranked certain preferences including service, reliability, cost and so on. Each actor suggested they ranked non-cost factors more highly and suggested every other actor prioritised cost! As well as a lack of understanding of their supply chain partners' preferences, this cost focus was always short term and never included unquantifiable or more remote risks. In the same way, until recently, decarbonisation measures were avoided because they were not understood and emissions could not be measured. Now GLEC (Global Logistics Emissions Council) and others have provided the tools and action is being taken to reduce greenhouse gas emissions.

Redesign will come about when different stakeholders within the supply chain and beneficiaries of it provide pressure. They cannot do so without data, here being the calculated cost of risks taken. At one level of the supply chain, the CEO has little incentive to consider shifting a manufacturing base to a more expensive (in normal operational terms) but lower risk environment, especially given the transition costs, when the risks cannot be quantified and his personal KPIs focus only on short-term profits.

A significant problem for defining a model for risk is that many of the consequences or costs of an occurrence may be borne by society. During the Covid crisis, some businesses have benefitted from significant sales increases and enhanced margins, whereas society and in some cases the wider environment have suffered negative consequences, many of which we will not fully understand for some time.

The obvious argument runs that design changes have costs and cost increases run through the supply chain. Therefore, if we wish to be more

(continued)

resilient, more stable in a volatile world, will the consumer or taxpayer accept the cost or will we simply be undermined by competition? Before we get to the position where we have no choice and dramatic events force supply chain changes, we need to agree how to judge the costs of such risks and reskill the supply chain to manage and take the opportunities of change.

Taking Thiell and Wilmsmeier's ten dimensions, academics could usefully analyse the projected risk factors associated with choices, based on specific company sectors (product inputs and other variables) and location. They should then work with supply chain specialists to consider how these theoretical risk factors would affect the supply chain and the possible costs or production/sales impact. The aim could be to develop a database of relevant impact ratios for particular supply chains assisting the redesign without starting from scratch. This would be a more suitable version of the market entry risk factors that companies often utilise, but specifically adapted for the supply chain. There are academic models that forecast the likelihood of natural erosion on rail and road routes, landslides and resultant impassable routes. Logistics managers know the effects and costs of a failure in a key route or corridor—many have suffered the effects of the 2017 Rastatt tunnel collapse and the more recent landslide closing the Rhine Valley rail route.

There will be significant opportunities arising from change and understanding how complex supply chains can be both more stable and agile. Staying flexible enough to adjust to events and yet stable enough to give confidence to customers or consumers will define the winners. Who will provide the data and model to make our impact ratio database possible? That is surely a worthwhile collaborative challenge for the academic and private sector communities.

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Supply Chain Transparency Using Blockchain: Benefits, Challenges, and Examples

Yao Cui and Vishal Gaur

1 Introduction

The importance of transparency in supply chains has never been higher. There are many factors that contribute toward a growing need for transparency across industries. Perhaps the most prominent of these is the periodic occurrence of costly supply chain disruptions and shortages due to both natural and man-made causes. Just in the past 15 months, the COVID-19 pandemic, the semiconductor chip shortage, and the Suez Canal blockage have reminded companies of the need for greater transparency and visibility in their supply chains (see, e.g., Berger (2021), Boston et al. (2021), and Yaffe-Bellany and Corkery (2020) for news coverage of these topics). Another factor is the need for environmental and social responsibility driven by both consumers and regulatory policies. Companies increasingly need to measure the environmental footprint of their products, take steps toward sustainable sourcing, and ensure that there are no animal or human rights abuses in the areas where they operate their supply chains. Thus, they need to know how their products are manufactured, transported, and consumed. Further, recent regulations enacted in developed countries now require drugs and food product manufacturers to provide traceability in order to improve safety and reduce illnesses.

Blockchain technology, introduced in 2008 for the Bitcoin cryptocurrency platform, provides a method to improve transparency in supply chains. In the last few years, successful proofs of concept of this technology have been demonstrated for many applications, some of which have gone into production at scale. Previously, companies had faced technological hurdles in adapting blockchain from cryptocurrency to supply chain applications. However, these hurdles are gradually being overcome. Indeed, companies today have templates available to implement blockchain-based solutions through platforms such as Ethereum and Hyperledger

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Table 1 Summary data on blockchain adoption in payment systems and other industrial applications from annual surveys published by Ripple

Survey year	2018	2019	2020
Number of respondents and countries	676; 21 countries	1053; 21 countries	854; 22 countries
% of respondents in payments related use cases of blockchain	18% in or near production	35% in or near production	59% in or near production
% of respondents running at least a payments blockchain POC who are exploring other applications	33% interested in expanding scope to other areas	33% interested in or seeking to expand scope to other areas	98% deployed in other areas, supply chain is the most common (62% in production), followed by trade finance (51% in production)
Growth stage of blockchain in payments	Proving value and feasibility	Moving to production	Expediting move to “go live”

and cloud-computing providers such as Amazon AWS and Microsoft Azure. Thus, supply chains have emerged as one of the most promising areas of application of blockchain. Annual surveys published by Ripple provide a glimpse into these trends (see Table 1). Although these surveys are focused on payment systems, they are useful because payments are an integral part of supply chain management. The surveys show a steady increase in the number of companies developing and deploying blockchain for payments and a growing interest in other applications of blockchain, especially in supply chains (Ripple, 2018, 2019a, 2020).

In this chapter, we examine evidence of successful applications of blockchain technology in supply chains in the light of recent developments. The chapter is based on our research in blockchain technology, a review of industry publications and websites of blockchain firms, and interviews with two companies, DLT Labs and DIBIZ, to understand the status and value proposition of applications. We classify supply chain applications of blockchain into three stages: the simplest are those focused on cost-efficiency and process improvements, the next layer of applications uses blockchain data to improve supply chain optimization, and the third layer of applications is related to new and innovative use cases. We describe these developments as follows. We first provide a brief introduction of this technology and highlight differences between cryptocurrency and supply chain applications in Sect. 2. Then in Sect. 3, we discuss potential benefits of blockchain in supply chain management and challenges associated with its implementation. In Sect. 4, we use examples from practice to discuss the three types of applications that have emerged, the evidence of value and success that is available thus far, and how the use case for blockchain technology in supply chains is expected to evolve in the future. We conclude with a discussion of the academic literature and future trends in Sect. 5.

2 Blockchain

Blockchain is a protocol for users in a peer-to-peer network to conduct secure, tamper-proof transactions with each other without the need for a trusted third party. This technology was first proposed for the Bitcoin cryptocurrency platform in Nakamoto's famous 2008 paper, but has gained widespread interest for applications in other areas including supply chains, banking and finance, real estate, international trade, and even art. In this section, we discuss the key elements of blockchain technology in the context of cryptocurrency networks and identify distinguishing aspects that would be needed to adapt this technology for supply chains. This distinction arises because cryptocurrency networks are entirely digital, whereas supply chains have both digital and physical components. Moreover, the use cases in supply chains differ from those in cryptocurrency networks.

We define the elements of blockchain as follows. For detailed definitions, we refer the reader to Nakamoto (2008) and Antonopoulos (2017).

Digital Token Transactions between participants in a cryptocurrency network are conducted in digital currencies such as Bitcoin. Each Bitcoin is a *digital token* with a unique identifier and value, similar to the unique number on each dollar bill. Similarly, each participant in a cryptocurrency network has a unique public key-private key pair, which it uses to transact securely on the network. Encryption provides anonymity and security, so that no one else can hijack a user's account.

To adopt this architecture in supply chains, each unit of inventory is tagged with a unique identifier, which is the digital token associated with that unit of inventory. Inventory can represent a single item or it can represent batches of different sizes—a case, a pallet, a truckload, or a container. Moreover, not only product inventory, but also documents, such as purchase orders, bills of lading, invoices, and certifications, can be assigned digital tokens and represented on the blockchain. Further, each participant in a supply chain blockchain network has a unique identifier. Note that a firm that seeks to capture all its supply chain activities would need to record the movement of inventory in different stages of its operations, including production, handling, and transportation. Thus, a firm may have thousands of "participants" on the blockchain corresponding to different workers, machines, sensors, and locations in its network.

Digital Transaction A digital transaction is the transfer of ownership of a digital token from one participant to another. In a supply chain, every movement or transformation of inventory can be represented as a digital transaction that is generated when the tag associated with that unit of inventory is scanned by a participant. For example, when a carton of milk passes through a temperature sensor, this activity can be represented as a transaction conducted by that sensor. The data associated with this activity would include the time stamp, the digital token of the milk carton, the identifier of the temperature sensor, and the temperature reading. Similarly, when two components are assembled together by a worker to create a finished product, this activity results in a digital transaction containing the identifiers of the components, the finished product, and the worker. Thus, note that to represent supply chain activities on a blockchain requires a broad interpretation of "transaction" since actual goods may not change ownership in every supply chain activity.

Managers need to decide which of the data components associated with a transaction or event to store on the blockchain. One approach is to store the data components in a database record and include a hash or encrypted signature of that data record on the blockchain. This approach ensures that the data are readily available for management tasks, while the blockchain ensures that the data are secure from the risk of getting modified in the future. Another approach is to store the data directly on a blockchain. This approach can be useful when only a limited amount of data is captured, such as regarding the movement of inventory in the supply chain.

Components of a Block A digital transaction is stored on the blockchain as follows. Suppose there is a transfer of a digital token from Owner 1 to Owner 2. Then, Owner 1 creates the digital transaction by putting together Owner 2's public key, the identifier of the digital token, and a hash of the bits in this transaction and the previous transaction, and then signing this record with her private key. The same method is used to construct a block of several transactions, i.e., a hash of the current block and the previous block is created, and then the block is signed by its creator. Hashing a block with the previous block makes it impossible to overwrite a block in the middle of the blockchain without rewriting all subsequent blocks. This design, when combined with distributed consensus, makes the data entered on a blockchain *irrevocable* or *immutable*. As noted above, this method can also be modified to secure the companion data associated with a transaction without having to store the entire data on the blockchain.

Note that the blockchain, constructed in this fashion, necessarily maintains a complete history of the transactions among the participants. This storage of transaction data is necessary to demonstrate proof of ownership in cryptocurrency networks. In supply chains, this same approach helps construct an audit trail for mitigating risk and ensuring compliance. As a result, the blockchain entails considerable burden on storage space. However, the blockchain protocol allows methods to reduce the length of the chain by pruning previous blocks using Merkle trees.

Distributed Consensus A cryptocurrency blockchain needs a mechanism for a user to know that the digital token that it is receiving has not already been transferred by the payer to some other user. This is called the *double-spend problem*. A blockchain platform uses distributed consensus as a mechanism to establish proof of ownership and conduct transactions without the need for a trusted third party, such as a central bank or a financial institution. In this method, each participant maintains her own copy of the blockchain, so that the blockchain is referred to as a *distributed ledger*. Participants compete with each other to add new blocks to the chain by solving a computationally hard puzzle. The participant who solves the puzzle first publishes her *proof of work* for verification and adds a new block to the chain. Other participants update their own chains to the longest chain and the cycle repeats.

Distributed consensus is achieved when more than 51% of the participants confirm a block.

The proof-of-work protocol is permissionless, i.e., it allows the blockchain to be public and the participants to enter or exit the platform freely. Thus, a blockchain network operating in this manner provides proof of ownership in a decentralized world consisting of anonymous participants without the need for a central authority. The robustness of the proof-of-work protocol to different types of attacks is an active research topic in computer science (see, e.g., Pass et al. (2017)).

In contrast to the needs served by the proof-of-work protocol, supply chains require participants to have *known* identities in order to meet the goals of transparency and traceability. Therefore, instead of allowing unlimited entry and exit, blockchain systems designed for supply chains should be permissioned and limited to known entities.

Smart Contracts When the data required for a transaction have been codified and secured on a blockchain, it can be applied to automate decision-making. This is done through smart contracts, which are computer programs that verify the completion of tasks and take pre-determined actions, such as making automatic payments. Although smart contracts have been of limited use in cryptocurrencies, they can be quite useful in industrial applications. We discuss examples of such applications in Sects. 3 and 4.

3 Benefits and Challenges in Supply Chains

The main benefit of blockchain for supply chain management is that it can provide a detailed and irrevocable audit trail of supply chain activities. Since all widgets and all participants on the platform are given digital identities, the blockchain enables participants to track and trace the transactions associated with each widget. Although the construction of an audit trail is theoretically possible in the non-blockchain world, it is practically difficult and costly to record all the material, information, and financial flows associated with each transaction for future retrieval. A blockchain provides this facility with accuracy and reliability. However, despite these benefits, the adoption of blockchain technology in supply chains is not straightforward. In this section, we describe the benefits and challenges in the adoption of blockchain in supply chains.

3.1 Benefits

Consider an example of a packaged food products manufacturer that produces and supplies baked croissants to a network of retail stores. Through a blockchain, it is possible to trace the movement of a batch of croissants through the various stages of the supply chain from raw material procurement to retail sales. This data is beneficial in many ways:

- Inventory management involves the complex task of keeping track of multiple purchase orders, shipments, and invoices. Many errors can creep into this process, such as delayed or incorrect shipments and missed payments. Suppose the firm has a dispute with a buyer firm regarding an erroneous shipment. Normally, such disputes are resolved manually, which is costly and time consuming. With traceability of purchase orders, shipments, and invoices, it becomes possible to resolve disputes much more easily in an automated fashion.
- Suppose the firm needs to execute a product recall. It will be able to quickly and accurately identify other products in the same batch that might have been contaminated and will also be able to locate them in the network.
- The traceability data can be applicable in supply chain financing. To see this, suppose the firm needs to obtain a working capital loan from a bank against an order. The firm will be able to demonstrate the receipt and fulfillment of the order to the bank. Since the data on a blockchain is immutable, it provides reliability for contracting with the bank. It can enable the firm to access loan funds more readily and can also reduce the lending risk borne by the bank.
- Finally, the blockchain data can provide an infrastructure backbone for supply chain optimization. From this data, the firm would be able to track the remaining shelf life of each batch of inventory. Thus, the firm can reduce food waste by identifying batches that are closer to expiration and allocating them to high volume stores or potentially selling them at a markdown. Sophisticated perishable inventory models can benefit from such information, which is currently hard to obtain in most supply chains in practice.

Integration with New Sources of Data The above benefits are based directly on supply chain transaction data. Additionally, supply chains now have the ability to collect not only transaction data but also supplementary data regarding the condition of inventory and processes. Agricultural sensors are used to monitor soil quality and irrigation, and IoT devices in manufacturing and logistics can monitor the running condition of machines, worker parameters, inventory storage conditions, greenhouse gas emissions, and quality attributes of products. Moreover, at a macro-level, supply chain network data on certifications, disruptions, and regulatory disclosures is becoming more readily available. For example, the European Space Agency collects and disseminates satellite data on a wide range of metrics including land management, marine environment, and climate change (European Space Agency, 2015). Similarly, the World Wildlife Fund has set up its own blockchain platform, titled OpenSC, to track the sourcing of products from illegal fisheries and areas with animal rights and human rights abuses (World Wildlife Fund, 2019). When such new sources of data are incorporated into a supply chain traceability system, they can be beneficial in both downstream and upstream operations. This can enable companies to achieve societal sustainability goals as well as commercial objectives such as improving agricultural yield or manufacturing quality.

Comparison with Alternative Technologies A common question is whether a blockchain is necessary for traceability in supply chains or if centralized databases in a non-blockchain world can provide the same benefits. In our view, centralized databases are indeed capable of providing these benefits, but there are practical challenges. Different companies and agencies use different means to store data, ranging from Excel spreadsheets to paper trails to ERP systems. The definition and storage of data across these methods is often not standardized, which makes it difficult to achieve traceability across systems. For example, even within the same organization, there often are multiple instances of enterprise resource planning (ERP) systems (Gaur & Gaiha, 2020). Further, small-scale farmers and producers at the source of a supply chain may have no means to store data. In such a situation, constructing a trace of a product to its source is extremely difficult. A blockchain system can make it possible to gather and record data from different systems without requiring changes to those systems.

Moreover, since a blockchain provides a distributed and immutable record of events, it can help validate the accuracy of data and generate trust among supply chain partners. This feature is especially useful in applications that deal with regulatory subjects such as certification, dispute resolution, or contracting. For example, a bank can participate in a supply chain platform to verify transactions before it issues new collateralized loans to a firm.

3.2 Challenges

Many industry experts and academic scholars have remarked on the hype associated with blockchain (e.g., Higginson et al., 2018; Iansiti & Lakhani, 2017). Iansiti and Lakhani (2017) describe blockchain as a foundational technology rather than a disruptive technology, and predict that the industrial adoption of this technology could take decades. They compare it to TCP/IP (Transmission Control Protocol/ Internet Protocol), which laid the foundation of the Internet and underlies most of the Internet services we use today. By drawing this parallel, they propose that the industrial adoption of blockchain could be classified into four types of applications: single-use, localized, substitute, and transformative. Bitcoin payments are an example of single-use applications, whereas self-executing smart contracts would be transformative. Gaur and Gaiha (2020) further studied supply chain pilot projects across a cross section of companies and found that blockchain could solve long-standing supply chain problems, but its successful adoption would require addressing challenges related to governance, consensus protocol, and security. Such challenges are important for firms to overcome to successfully adopt blockchain in their supply chains. Thus, we discuss them in this section.

Consensus Protocol The capacity of a blockchain network depends on the number of transactions in a block and the rate at which new blocks can be added. The latter is limited by the consensus protocol to improve reliability under risk of attack. The puzzle-based proof-of-work protocol to achieve distributed consensus is not only not suited to permissioned blockchains but is also too slow for the volume and rate of transactions in a supply chain. To illustrate this, Fig. 1 shows the historical number

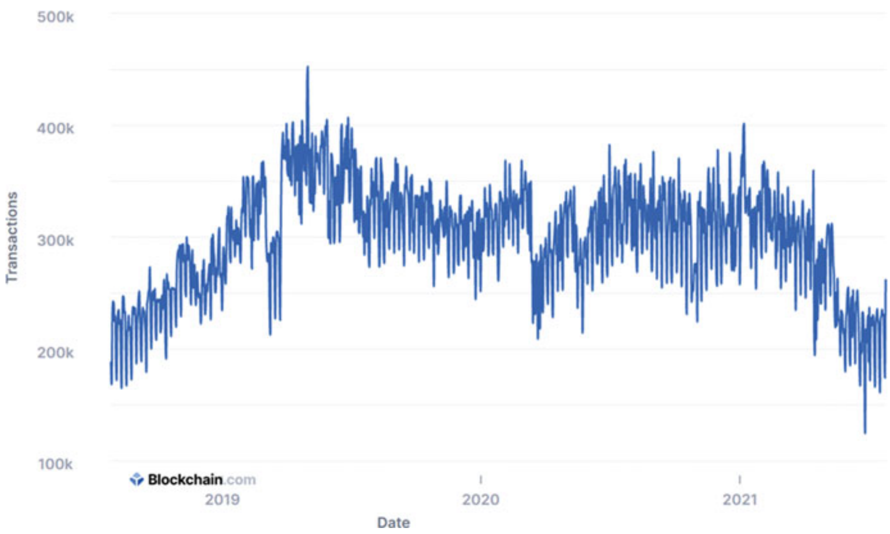

Fig. 1 Total number of confirmed Bitcoin transactions per day during July 2019–July 2021 (data source: https://www.blockchain.com/explorer)

of confirmed transactions per day over a 3-year period from July 2019 to July 2021 on Bitcoin, which is the largest cryptocurrency network. The highest number of transactions per day was 500,000, which translates to 5.8 transactions per second. In contrast, the pharmaceutical industry conducts 33–55 million supply chain transactions per day on average. Therefore, a proof-of-work protocol may not fit the requirements of supply chains, and may have to be replaced with simpler protocols that can provide a faster transaction rate without sacrificing security and can also avoid the energy consumption of a proof-of-work protocol.

Data Governance Implementing a blockchain does not absolve a firm of the need to maintain the security of the physical (real) supply chain. Although a blockchain provides an immutable digital record, participating firms still have to ensure that malicious products or components are not introduced into the supply chain and that the data entered on the blockchain accurately mirrors the activities in the real supply chain. This requires a system of checks and balances to verify the accuracy of the blockchain data compared to the physical supply chain. For instance, data reliability could be improved by replacing manual data entry with "Internet of things" (IoT) devices that are tamper-proof and automatically record data.

Data Access Control Besides improving governance and reliability, supply chain managers would also have to make other design decisions to construct a blockchain for their businesses. They have to decide what data to include on the blockchain, what databases to associate with the blockchain to store supplemental information, and with whom to share access to the blockchain and associated data across the supply chain. Answering these questions would require creating and testing new data coding standards and access protocols.

Data Integration Consider the previous example of a manufacturer of baked croissants. To assess the remaining shelf life of each unit of inventory in the warehouse, the manufacturer would need to integrate inventory location data from sensors in the supply chain with shelf life data from manufacturing, which might be stored in a separate database. The manufacturer would also have to determine the value of sharing this information with its retail customers. Consider another example of a firm that uses temperature sensors as IoT devices to measure temperature conditions in a cold storage and record the data on a blockchain. This data would have to be integrated with inventory location information on the same or other blockchains in order to assess the condition of each unit of inventory. Thus, to apply blockchain technology in supply chains, firms have to not only adapt the technology to supply chain processes but also create new standards and applications for sharing and using the recorded data.

4 Examples of Applications

In this section, we illustrate supply chain applications of blockchain with examples. We selected these examples based on a review of industrial publications and websites of blockchain firms, and spoke to two companies, DLT Labs and DIBIZ, to gather further insights. We classify applications into three stages of value addition as shown in Fig. 2: The first stage is to improve process efficiency in existing tasks by making data visible across the layers of the supply chain. The second stage is to

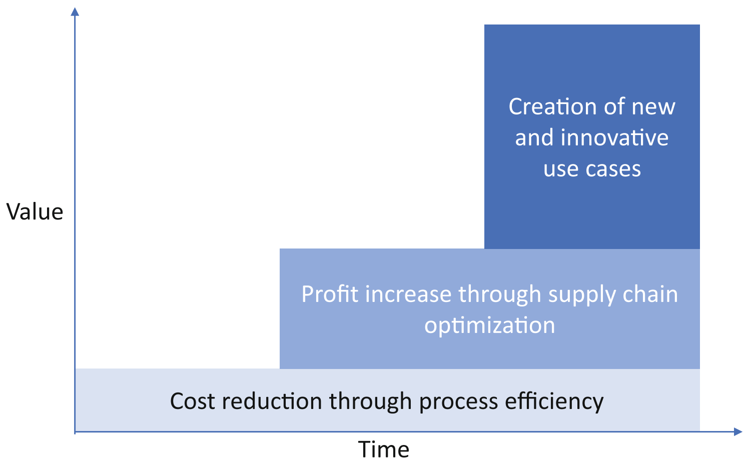

Fig. 2 Stages of value addition of different types of blockchain applications in supply chain management

optimize decision-making using traceability data. Finally, the third stage is to use traceability to meet regulatory and sustainability targets and create new value-added products. We next discuss these application cases.

4.1 Cost Reduction Through Process Efficiency

Supply chains are exceedingly complex, requiring vast amounts of data, granular decision-making, and coordination. Performing these tasks entails processing costs and is rarely flawless. Blockchain can be useful in supply chain management for reducing manual tasks, making it easier to discover and resolve execution errors, and increasing the speed of decision-making through faster information availability. We regard this as the first stage of blockchain applications because it has the potential to provide tangible and immediate gains in existing processes without further innovation. To illustrate these applications, we discuss two examples of pilot tests and implementations conducted by companies.

Our first example relates to trucking logistics for Walmart Canada, which uses more than 70 third-party freight carriers moving 500,000 loads per year to supply products to its stores (see Berthiaume (2020) and Smith (2020) for details). Each load results in an invoice whose charge is calculated from close to 200 variables, such as demurrage charges that are applied when a truck is held up at a location longer than the allotted free time. Most of these variables are based on a paper trail, which can lead to conflicting pieces of information. About 70% of the invoices are disputed, resulting in costly manual processing and delayed payments.

Walmart Canada joined with DLT Labs and Bison Transport to implement a blockchain-based system to solve this problem. The system uses GPS devices, geofencing, temperature sensors, timestamps, and other IoT devices to track the movement and condition of freight and records this information on a blockchain. Freight carriers then collate all the data and generate a verifiable invoice, eliminating costly and error-prone manual steps. Walmart Canada reports that this system has been implemented at most of the freight carriers, and as a result, invoice disputes have declined by 97% and payments to freight carriers are being made faster. The company reports savings of about $30 million in the cost of manual work required to resolve disputes and due to the benefits of real-time visibility into planned and unplanned shipping costs. Carriers have also saved cost and improved their balance sheets due to accelerated payments and reduced administrative overhead. To implement this system, Walmart Canada required freight carriers to install sensors for data collection, and a permissioned blockchain solution was created by DLT Labs on Hyperledger Fabric. We spoke with Loudon Owen, CEO of DLT Labs, and learned that this effort has resulted in spillover benefits for freight carriers, such as access to lower cost financing based on Walmart's superior credit rating and the capability to expand this system to other customers.

Our second example relates to cross-border payments in supply chains. Such payments require a cumbersome process through multiple intermediaries in the banking system, which can take 3–9 days (Ripple, 2019b). First the buyer firm makes the funds available to its bank. The funds are then sent to the supplier's country through correspondent banks. Finally, the supplier's account is credited. Each of these steps takes at least 1 day, and the cost of liquidity required to fund the transaction falls on the buyer or the supplier. To see this, suppose that a buyer firm makes \$100 million of cross-border payments in a year, each payment requires 6 days, and the cost of borrowing is 10%. Then, the firm needs to borrow \$1.64 million of cash (= \$100 million $\times$ 6 days/365 days) to execute these payments, resulting in an annual interest cost of \$164,000.

Ripple has created a blockchain-based global payments network, called RippleNet, as an alternative to this traditional system of international payments to improve the speed and reduce the cost of transactions. The network is based on a native digital asset, XRP. A financial institution seeking to send money from country A to country B buys XRP in the currency of country A and then sells XRP to get funds in country B in the local currency. This simpler process cuts down the cost and time of cross-border transactions dramatically, thus releasing costly liquidity from the system. This method is used not only in supply chain payments but also by the online gig economy platform Freelance.com to make small-scale payments to freelance workers across the globe.

The above examples illustrate the value of blockchain in improving execution efficiency and reliability in supply chain processes. There can be many other such opportunities, such as in international trade (see, e.g., TradeLens developed by IBM and GTD Solution, Inc.) or in mitigating the nefarious problem of inventory data inaccuracy studied in the academic literature in operations management (Raman et al., 2001).

4.2 Profit Increase Through Supply Chain Optimization

We consider the next stage of applications to be those that leverage the greater data transparency from a blockchain to optimize decisions. We illustrate this use case with the example of DIBIZ, a blockchain-based startup firm based in Singapore, which has implemented a platform for providing traceability in the palm oil supply chain. In our search, we have also come across other recently emerged blockchain platforms that aim to improve supply chain traceability, such as OwlTing, VeChain, Bext360, Skuchain, and BlockVerify.

DIBIZ collects and maintains transaction-level data across all the links of the palm oil supply chain: farmers → dealers → mills → refineries → consumer packaged goods (CPG) companies. The data recorded on the platform can be used to verify the quality and source of palm oil and to make fair payments to all stakeholders. DIBIZ discovered that dealers perform a key logistics task in this supply chain by picking up palm fruit bunches from farmers and transporting them to mills. Because of limited information sharing in the supply chain, it is challenging for dealers to optimize the scheduling decisions for pickups and deliveries and to allocate truck capacity across different tasks. The cost of these inefficiencies falls not only on dealers but also on farmers and mills in terms of wasted labor capacity and potential deterioration of fruit quality. In fact, this problem is similar to that described in the classic case study on National Cranberry Cooperative (Miller & Olsen, 1983). The blockchain solution has enabled dealers to optimize the scheduling of pickups and deliveries by leveraging enhanced information visibility. One benefit of optimization is a reduction in the waiting time of trucks at the weigh bridges of mills and refineries, which lowers both operating cost and greenhouse gas emissions. Another benefit is an improvement in the quality of processed fruit, thus increasing its oil extraction rate (OER). DIBIZ estimates that for a mill producing 5000 tons crude palm oil per month, a 0.1% increase in OER can potentially increase revenue by approximately USD 65,000/year considering the current market price of crude palm oil at USD 1100/ton.

While DIBIZ provides one example, information visibility is known to be valuable in the optimization of many types of supply chain decisions. Gaur and Gaiha (2020) report examples from two manufacturing companies that see value from transparency for optimizing ordering and inventory allocation decisions in the upstream supply chain. Components and capacities can be allocated to orders placed by customers as soon as an order is received with full transparency and without the risk of a double-spend problem. This can improve supply chain coordination and reduce uncertainties. Other applications of optimization include managing perishable inventory and reducing food waste using data on product shelf life.

4.3 New and Innovative Use Cases

Our third stage consists of applications that generate value by discovering and meeting new customer needs. In this stage, we include applications that enable companies to track and trace their products for regulatory compliance and sustainability. We also discuss the example of Ripe.io, a food blockchain startup that has discovered that blockchain data can be applied to meet new customer needs.

Regulatory compliance and sustainability have emerged as the major drivers of blockchain adoption in the food and drug industries and in consumer products, more broadly. We highlight three major examples of such regulations. First, the U.S. Congress enacted the Food Safety Modernization Act (FSMA) in 2011 to improve the prevention of foodborne illnesses.[1] Recognizing that food safety is a shared responsibility of the participants of the global food supply chain, the Food and Drug Administration (FDA) has stipulated rules to implement FSMA, including a requirement for firms in the food supply chain to maintain traceability records of key data elements and critical events related to growing, receiving, transformation, creation, and shipping of food. The FDA has also sponsored pilot projects over time to enable

[1] Food Safety Modernization Act (FSMA). URL: https://www.fda.gov/food/guidance-regulation-food-and-dietary-supplements/food-safety-modernization-act-fsma

companies to test traceability systems, which has led to blockchain-based initiatives such as the IBM Food Trust (IBM, 2019).

The second example is the Drug Supply Chain Security Act (DSCSA) of 2013, designed to improve traceability in the distribution of prescription drugs in the U.S. to help protect consumers from exposure to contaminated, stolen, counterfeit, or otherwise harmful drugs.[2] The act outlines steps to build an electronic, interoperable system to improve the detection of such drugs and their removal from the supply chain. The act also has a deadline of 2023 by which companies must provide such capability. To facilitate the implementation of the act, the FDA announced a DSCSA Pilot Project Program in 2019, which led to pilots such as those by a blockchain startup MediLedger to validate the ability of blockchain to meet the track-and-trace requirements of the act (Hoffman & Hills, 2020).[3] The creation of this system is ongoing and it is unclear at this time if the FDA will use blockchain to implement the DSCSA. The European Union introduced a similar regulation in 2011, called the Falsified Medicines Directive, to combat fake medicines and tampering (McCauley, 2020).

Our third example relates to sustainability goals. The United Nations in 2015 created the 2030 Agenda for Sustainable Development, which includes 17 sustainable development goals. There is now a growing awareness of sustainability among both corporations and consumers. We see examples of traceability being applied to reduce the environmental impact of the products we consume. To wit, corporations such as Hewlett-Packard, The North Face, and Patagonia are making efforts to manufacture products using ocean-bound plastics; and CPG brands such as Nestle, Procter & Gamble, and Unilever seek to improve sustainable sourcing of agricultural products used in their products. Thus, regulations and sustainability goals are an important driver of the use of blockchain to provide traceability.

Traceability data can also lead to the creation of innovative products. Ripe.io, a blockchain technology company for agricultural produce, found that the taste of food varies with growing conditions and that blockchain can enable a food supplier to segment its market by taste (Food Logistics, 2017). The company collects data on variables such as soil, irrigation, and temperature in the growing period and integrates this data with tracking of batches of tomatoes from production to consumption. This enables them to predict the quality and ripening period of tomatoes as a function of growing conditions and to allocate produce according to the requirements of different market segments. Ripe.io has piloted this use case with Sweetgreen. We note that in this type of application, the utility of blockchain is in providing traceable data for new value-added products. This contrasts with some other uses of blockchain, where the value is in providing trust for contracting and

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[2] Drug Supply Chain Security Act (DSCSA). URL: https://www.fda.gov/drugs/drug-supply-chain-integrity/drug-supply-chain-security-act-dscsa

[3] Food and Drug Administration. 2019. Pilot Project Program Under the Drug Supply Chain Security Act. URL: https://www.federalregister.gov/documents/2019/02/08/2019-01561/pilot-project-program-under-the-drug-supply-chain-security-act-program-announcement

dispute avoidance. In fact, the parties already trust each other and are using blockchain as a mechanism to collect data from different systems.

Another type of innovation is to create marketplaces that help match supply and demand in uncertain markets. During the COVID-19 pandemic, traditional supply chain linkages for agricultural products were thrown into a disarray due to disruptions. As a result, suppliers had to scramble to find new buyers for their products and buyers had to look for new sources of supply. Ripe.io created a matchmaking community to connect local farm and food businesses with institutions, grocery stores, and restaurants to serve this need. Although a marketplace platform does not necessarily require a blockchain, in this case, Ripe.io's blockchain platform enabled the company to utilize its existing traceability and data-sharing capability to create a flexible and reliable supply chain from local farms to buyers. Similarly, DIBIZ is building a marketplace to connect participants in the palm oil supply chain with each other. The marketplace leverages the inventory flows that have been recorded on the blockchain and adds price discovery and matchmaking tools. Such services can improve the incentives for sustainable farming by making it easier for farmers to demonstrate sustainability and get a better price on their produce. In fact, such data sharing could become the harbinger of new flexible supply chains in the future.

5 Discussion

Many companies in the recent years have been testing pilot implementations of blockchain in supply chain management. In this chapter, we evaluate the status of and evidence of value from such implementations using a few selected examples. We conclude from these examples that blockchain can indeed be successful in improving supply chain traceability, and can yield benefits in execution efficiency, supply chain optimization, and creation of new innovations.

Along with a growth in applications of blockchain, recent academic research in the operations management discipline has investigated how supply chain operations can be impacted by, and should innovate with, blockchain. We conclude this book chapter by highlighting the types of topics that are being addressed by some of the recent academic research in this area:

- Researchers have investigated *incentives* of firms in a supply chain to form the right blockchain consortium. Although visibility over actions of supply chain partners can improve operational decisions, firms may have reservations about sharing their own data, especially when the supply chain consists of competing firms. Thus, firms may want to form their own blockchains, even though this would limit the benefit of blockchain. Iyengar et al. (2021) design a transfer mechanism to resolve such an adoption failure, so that creating a single blockchain for the entire supply chain would be feasible.
- Supply chain partners can design *new contracting terms* with blockchain-enabled traceability (Cui et al., 2020; Dong et al., 2020). For example, once a defective

batch is detected, the traceability information from the blockchain can enable the sellers of agri-food products to accurately identify which products are affected and need to be recalled. In this case, the seller would only need to penalize the manufacturers who are responsible for the defective batch. As another example, manufacturers who face a disruption risk may have to purchase raw materials from a more expensive supplier when the primary supplier is being disrupted. In this case, blockchain's automated data recording through IoT devices can enable the manufacturer to credibly prove the source of raw materials and implement more flexible wholesale price contracts where the wholesale price is automatically charged via a smart contract based on which supplier is currently being used (Cui et al., 2021).

- Researchers have also studied questions related to the design of blockchain, such as the *data access control*. For example, by analyzing a supply chain consisting of multiple manufacturers' sourcing from a common supplier, Cui et al. (2021) find that it may not be optimal for all firms to have access to the entire supply chain's logistics data. Depending on the supply chain's production capacity, the optimal design of a blockchain that maximizes the total supply chain profit can be one that limits the competing manufacturers' access to the logistics data.
- Research is also ongoing into different types of applications of blockchain. Chod et al. (2020) investigate the *supply chain financing* benefits of blockchain and develop an open-source blockchain protocol that leverages Bitcoin to provide supply chain transparency at scale and in a cost-effective way. Sumkin et al. (2021) examine the benefits of blockchain for ethical sourcing in the diamond industry in a competitive market equilibrium model.

These academic studies aim to provide theoretical guidance for addressing the challenges of blockchain implementation and ascertaining its value. Thus, we observe that industry development and academic research are both moving in the same direction of greater application of blockchain in supply chains.

Management Perspective on Blockchain Powered "Sustainable Marketplace"

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As the world's most traded vegetable oil commodity, palm oil has been used around the world for food and nonfood applications and can be found in most food, personal, and home care products. It is also the cheapest vegetable oil due to its high productivity (eight to ten times soybean oil, its nearest competitor). This has created a huge demand for palm oil for both food and fuel (biodiesel) globally. The palm oil industry has been under constant attack for deforestation, destruction of wildlife habitats, loss of biodiversity, exploitation of labor, greenhouse gas emissions, and therefore its overall impact on climate

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change. The industry has set up several sustainability certifications systems, starting with the Roundtable for Sustainable Palm Oil (RSPO) in 2004, International Sustainability and Carbon Certification (ISCC), Malaysian Sustainable Palm Oil (MSPO), and Indonesian Sustainable Palm Oil (ISPO), the latter two being national standards. Despite over 17 years of concerted effort, only 20 million MT out of 78 million MT of palm oil produced annually is RSPO certified. The irony is that only 50% of the RSPO-certified palm oil fetches a premium in the market. Recently, Greenpeace has come out with a scathing attack on palm oil industry for "Greenwashing" highlighting that sustainability certification alone is not enough and that it does not resolve the many problems that plague the industry. The key issues that remain unresolved are lack of real-time end-to-end visibility, particularly for the 40% of global oil palm crop being produced by millions of smallholders, difficulty in getting smallholders to produce sustainable palm oil (only <2% of global sustainable palm oil comes from smallholders), and spreadsheet-based inferred evidence on traceability in the palm oil supply chain is a postmortem and does not proactively guarantee NDPE (No Deforestation, Peat, and Exploitation) compliance. Being a practitioner in the palm oil industry for over 30 years, grappling with these issues, I strongly felt that this problem needed a comprehensive and robust technological solution. We identified the social and environmental issues facing the palm oil industry and came to the conclusion that it could not be resolved by just a few MNCs with ethical practices and certification systems alone. This is how M. Srinivasan (my partner and chief operating officer of DIBIZ) and I conceived the idea of a blockchain-powered digital supply chain platform (DIBIZ) that can address all these issues in an indisputable manner by providing real-time information through immutable supply chain transaction records. The sustainable palm oil's trade value alone is about US$200 billion, considering at least five hops in the supply chain (smallholder-dealer-palm oil mill-refinery-end user). *A more rigorous and transparent approach is the need of the hour and that is exactly the solution that DIBIZ provides.*

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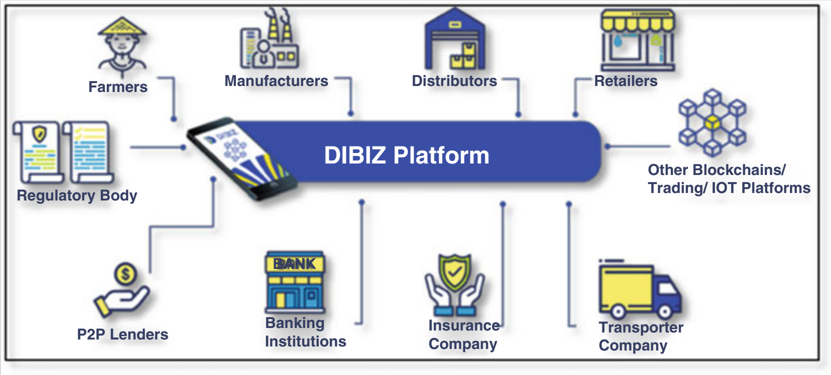

DIBIZ is a two and a half year deep-tech startup headquartered in Singapore with an operating office in Malaysia and a technology development center in Bangalore. It aims to solve the complexities and reduce the cost of sustainable supply chain by creating the World's first blockchain-powered "sustainable marketplace" for trading sustainable products. Using this platform, businesses can seamlessly connect with their trading partners to privately and securely exchange supply chain data without worrying about the IT systems implemented at every stage of the supply chain; the common data infrastructure facilitates communication and traceability to benefit the whole supply chain ecosystem. Previously, such supply chain data was collected and available only in a disjointed and staggered capacity, as seen from other traceability systems. With DIBIZ, we have been able to formulate a platform which emulates a "one-stop shop" ethos where all data, information, news, etc. across a global supply chain can be found in one place.

Across the supply chain, the DIBIZ marketplace does more than just price discovery; it acts as the world's first authenticated marketplace for sustainable products. The digital transformation modules on the platform include trade document management, certification and audit reports, geospatial analytics,

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and production and inventory management. The platform provides immutable granular data on a real-time basis, which provides the credentials for a truly sustainable supply chain with NDPE conformance. The standalone and network effects also ensure greater collaboration between stakeholders. Furthermore, last mile connectivity is guaranteed by bringing on board smallholders through the free DIBIZ mobile app which can work even without network connectivity in remote areas. As part of our CSR, DIBIZ has pledged 1% of its revenue to improve the livelihood of smallholders. This is a huge socioeconomic impact that we can bring about.

The DIBIZ platform also provides value-added technical features which improve trade flow significantly. It has the capability to provide direct access to low-cost trade financing from FinTech companies, digital banks, and investors who support ESG-compliant supply chains. It also has an in-built digitized workflow automation which improves productivity and a real-time traceability and tracking system of inventory with geospatial analytics. This ensures compliance to regulations for counterfeits and food safety and helps reduce the costs associated with product recalls. The knock-on socioeconomic effect created by this for smallholders around the world is significant; it aims to support and empower those who have previously never been afforded the privilege through real-time transparent pricing, quality assessment, and easy cost-effective access to agricultural supplies. Smallholders will now feel incentivized to practice sustainable agriculture as they can reap the rewards for it without being marginalized. The beauty of such a digital transformation tool is that each and every stakeholder on the supply chain has a value proposition both on a standalone basis and a multiplier effect through collaboration. Palm oil mills will benefit through better OER (oil extraction rate) through data analytics on FFB (fresh fruit bunch) quality, scheduling of supplies from smallholders, dealers, and estates. Just a 0.1% improvement in OER would be an additional USD 60,000/year in profits at a CPO (crude palm oil) price of USD 1000/MT. Similarly, palm oil refineries can have better control on inventory and provide end-to-end traceability to their buyers with geospatial analytics to command a premium for their sustainable palm oil. End users and MNCs will also benefit as the DIBIZ marketplace will provide greater visibility to sustainable palm oil supply, thereby reducing the huge premiums (USD 80–250/MT) that they are currently paying by sourcing from a handful of suppliers.

The DIBIZ platform was launched in October 2020 during the world's largest palm oil conference—POC2020—and has since started gaining good traction. The response so far has been very good and customer onboarding is in progress. 150,000 oil palm smallholders from the National Association of Smallholders Malaysia (NASH) have agreed to come on board. In addition to this, several palm oil industry associations and government agencies in Malaysia have shown an interest to use the DIBIZ platform to improve their

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sustainability credentials when dealing with MNCs. A pilot project with Fedepalma in Colombia is currently underway, and several other palm oil industry stakeholders are showing a very keen interest. The Ministry of Plantation Industries and Commodities (MPIC) in Malaysia is considering the adoption of the DIBIZ platform industry-wide. DIBIZ has also signed an agreement with Control Union (the world's largest certification body) to promote the use of the DIBIZ platform as a sustainability tool to ease the certification process among its over 1300 palm oil industry clients globally.

Since the launch of the DIBIZ platform for the palm oil vertical, there has been a great deal of interest from other verticals from different geographies to adopt the DIBIZ platform for their supply chains—aquafeed, olive oil, waste recycling, and other agri-supply chains like durian, rubber, timber, pepper, cocoa, etc. The platform architecture has been designed as "industry agnostic"; it would only require about 20% tweaking to adopt it to any vertical mainly due to the differences in production processes. Being a bootstrapped company, diversification to other verticals has been deferred until we get sufficient funding to allocate additional resources for it.

As part of the "Go to Market" strategy, DIBIZ plans to adopt the platform for other vegetable oils first and then later to other agricultural sectors. The Covid pandemic has caused serious disruptions in global supply chains, and the application of the DIBIZ platform to sectors like pharmaceuticals is also gaining momentum.

DIBIZ is a proud member of "Microsoft for Startups" and Microsoft "Sustainable innovation program" (the only B2B supply chain company in the 16 on the global list), "Oracle for Startups," and "ESRI for Startups" programs and has been awarded free credits and deep discounts. DIBIZ was also a finalist in the regional "Harvard New Venture Competition-2021" *for the Asia-Pacific region.*

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PI Meets Blockchain

Alfred Taudes and Gerald Reiner

1 Introduction to the PI

In 2006, the "Physical Internet" (PI) was mentioned the first time in *The Economist* (Markillie, 2006) without explaining the idea in more detail. In 2009, Benoit Montreuil was the first who developed, in collaboration with Russell Meller and Eric Ballot, a vision about the "PI" to rethink the core of logistics and transport supply chains (Pan et al., 2017).

Montreuil (2011) conceptually presented characteristics to reach his vision of logistics sustainability at a global level by addressing economic, environmental, and social dimensions related to technological innovations (e.g., smart and modular containers) as well as process innovations (Ballot et al., 2014). The following operations and supply chain management-related aspects presented by Montreuil (2011) are still of particular interest:

- Universal interconnectivity—to enable high performance logistics systems and related world-standard protocols.
- Distributed multi-segment intermodal transport—similar to the digital Internet in terms of sending e-mails. This may require for transport goods:
  - Distinct carriers and modes.
  - Synchronized transfer between hubs and nodes.
  - Platforms are required to enable open markets for transport requesters and providers.
- Unified multitier conceptual framework—always the same conceptual network is applied interdependent from the scale (i.e., processor, center, facility, city, state, country, continental, worldwide), similar to the idea of fractals that are of interest for the digital Internet (Lévy-Véhel et al., 2005).

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- Open global supply web—contrary to the state of the art that relies to a large extent on private supply networks.
- Digital transmitted knowledge and materializing products as locally as possible—the objective is to minimize physical moves and storages. The combination between the PI and open distributed production centers might be enabled by disruptive manufacturing technologies, e.g., additive manufacturing (cf. Kunovjanek et al., 2020).
- Open performance monitoring and capability certifications—key performance indicators are speed, service level, reliability, safety, and security.
- Reliability and resilience of networks—similar to the digital Internet, it is required that the "PI" warrants its own reliability.
- Business model innovations—innovative revenue models for the involved stakeholders seem highly relevant to enable the required collaboration.

Pan et al. (2017) provide an accurate overview about the "PI" state of the art in research as well as practice. The following aspects are relevant from a planning and management perspective (Pan et al., 2017):

- Conceptual research for open logistics system to enable a global Logistics Web.
- Research based on optimization and simulation modeling to assess the economic, environmental, and societal impact of the innovations related to the "PI."
- Solutions design research focuses on designing, engineering, and testing the technologies and processes enabling the "PI".
- Validation research is dealing with case study research, pilot studies, and living labs to learn from empirical research results and to derive managerial implications for the implementation roadmap.

Working together within the Logistics Web seems to be very crucial for a successful implementation of the "PI". Wankmüller and Reiner (2020) provided definitions for coordination, cooperation, and collaboration based on an extensive literature review that justifies this requirement: "Coordination" refers to a process of aligning, organizing, and managing actors' operational business activities where private information, risks, and resources are shared. "Cooperation" refers to a process of working on independent business activities toward a common (agreed-on) goal in a long-term view where communication is relatively informal, resources are separated, and risks are shared. "Collaboration" may be described as a process of strategically working together on a specific business activity where structures are aligned, communication channels are standardized, risks are shared, and resources are pooled in order to make them available for every partner (Wankmüller & Reiner, 2020). A common requirement of all these types of "working together" is the sharing of risks and revenues. This has to be addressed in the supply chain contracts developed for the "PI" in addition to the already mentioned requirements.

The vision of logistics sustainability at a global level has been specified in the roadmap toward zero emissions logistics developed by the European Technology Platform on Logistics "ALICE," i.e., zero emission (carbon-neutral) road transport should be achieved until 2050 (Punte et al., 2019). The European Technology Platform on Logistics “ALICE” identified the “PI” as the main European vision for logistics and supply chain management with the objective to develop strategies for research and market exploitation of logistics and supply chain management innovations (www.etp-logistics.eu).

To enable the “PI”, there are still several innovations required. The sub-chapter “Insights from the Top Management” will address the perspective of logistics service providers. Afterward Sect. 2 will provide methodological input for innovative planning and operations decision support. There is a need to design and implement innovative technologies to enable PI exploitation across the world; see Sect. 3.

2 Blockchain Architecture for PI Based on Ant Colony Optimization

According to Montreuil et al. (2010), the PI consists of several standardized elements prefixed by “PI-”. Containers contain the products shipped. They are manipulated, stored, and routed through the PI. The container side can distinguish between “handling containers” that cover the products, and “transportation containers” that provide the structural integrity of the goods. Contrary to transportation containers, handling containers will have to undergo substantial change to become PI-containers as in PI different logistics service providers must be able to process and mix containers of different customers in a secure way while keeping their content secret. Analogous to packets in the digital Internet, PI-containers will need an information header that describes their physical content and the information necessary for properly routing the products to the destination. According to Landschützer et al. (2015), PI-containers must contain a unique international identification to ensure traceability and protect content information. In order to enable the core functionality of allowing the mixing of different loads, they must be standardized both in form and mechanical strength, and it must be possible to stack and lock them. PI-containers are moved between PI-nodes by PI-movers such as transporters, conveyers, and handlers. PI-nodes perform logistic operations like sorting, storing, picking, composing, and shipping. PI-movers and PI-nodes must publish their KPIs, such as speed or service level, to enable clients informed routing choices.

Given the open distributed nature of the PI, it is natural to propose a blockchain architecture to support its operations. Hasan et al. (2021) point out a number of blockchain benefits for logistics and supply chain management, namely monetization and micropayments, incentives, penalties and rewards, transparency and fraud reduction, disintermediation via smart contracts, data integrity and immutability, smart containers tracing and tracking, and global shared identity and registry of PI-entities. They also discuss implementations based on Hyperledger Fabric and Hyperledger Besu.

Meyer et al. (2019) derive a blockchain architecture for PI based on an analysis of requirements mentioned in use cases. In their conceptional design, PI-containers are blockchain tokens storing identity and movement data. PI-movers are lightweight nodes that submit transactions and read and write container data, same as PI-nodes, who are full nodes storing the full blockchain. PI-organizations mine new blocks, participate in consensus, and govern the system. A problem with this design is that the algorithms for routing and task allocation are not specified. It is unclear on what basis tasks are assigned to PI-movers and PI-nodes and how a PI-container is routed through the logistic network.

In the PI philosophy, this should be done in a decentralized way, where coordination is achieved via fair and transparent mechanisms. Therefore, we propose another architecture involving blockchain technology. We build on the analogy between datagrams in the Internet and PI-handlers proposed by Sarraj et al. (2014) and let PI-containers be autonomous agents that make routing decisions based on their local knowledge and specific goals.

In our design, PI-containers have a wallet with tokens to reward PI-movers, PI-handlers, and PI-nodes for the services they are doing for the respective PI-container with utility tokens of the system. Upon dispatch, they receive a time, cost, and emission budget specified as separate amounts and a weighted goal function or caps and then autonomously decide on the routing taken needs like maximum temperature or special handling equipment into consideration. On their way through the PI, they automatically receive quotes and enter contracts with PI-movers, PI-handlers, and PI-nodes encoded as smart contracts on the blockchain. Payment is done automatically once the service contracted is reported by an oracle to the respective smart contract accounting for time, emissions, and cost, where separate tokens can be used for each aspect.

PI-nodes, PI-handlers, and PI-movers publicly announce their services and capabilities on the blockchain, and PI-containers ask eligible PI-nodes, PI-handlers, and PI-movers for quotations and locally select the best route based on a network of routing nodes that contain the latest information on latencies. Local operations at PI-nodes, PI-handlers, and PI-movers are scheduled using internal information systems in place (e.g., scheduling, load planning, warehousing, etc.), while smart contracts store operations committed and actual performance, so that the service levels of the different nodes are public blockchain knowledge.

An AntNet type of algorithm is proposed for the routing of PI-containers through the network in a decentralized fashion. AntNet was developed by Di Caro and Dorigo (1998) as an algorithm for adaptive best-effort routing in IP networks. It is based on the ant colony optimization framework, a meta-heuristic optimization technique which mimics the behavior of ant colonies to find shortest paths to food sources. In our proposal, PI-containers take over the role of ants and autonomously make routing decision as follows:

- After being submitted to the network at any PI-node, a PI-container autonomously takes the optimal path to its destination node in a step-by-step mode given its goal function and token budget.

P_{11}	P_{12}	...	P_{1N}
P_{21}	P_{22}	...	P_{2N}
	Routing Table		
P_{L1}	P_{L2}	...	P_{LN}

Stat (1)	Stat (2)	...	Stat (N)
Local Traffic Statistics			

Fig. 1 Routing information of a routing table, adapted from Di Caro and Dorigo (1998)

- PI-containers communicate indirectly by reading empirical time, route preference, and queue lengths information about all PI-nodes visited on a network of routing nodes.
- At each PI-node, a PI-container applies a greedy stochastic heuristic to select the next PI-node and PI-mover on the basis of the traffic information stored in the routing node of the PI-node by previously visiting measurement PI-containers taking account the current queue length at the nodes, the needs of the PI-container, its goal function and remaining budget, and the offerings made by the PI-nodes, PI-handlers, and PI-movers possible for the next step.
- Special measurement PI-containers are submitted from the PI-nodes to destination nodes to obtain a complete up-to-date view of the state of the network in routing tables attached to PI-nodes. The frequency of such measurements is set according to the share of traffic seen by each destination so as the exploration activity adapts to varying traffic conditions.
- Upon returning from the destination node, a measurement PI-container takes the same path back to the source node, and the local traffic statistics of the routing nodes visited are updated via the data collected by the measurement PI-container on the forward path.

Figure 1 depicts the information available at a routing table attached to a PI-node. The routing table stores probability values P_{nd} that represent the goodness of choosing node n as next node when the destination node is d, with $0 \leq P_{nd} \leq 1$, $n, d = 1, \ldots, N$, and $\Sigma P_{nd} = 1$. Starting from a uniform distribution, they evolve through reinforcement learning where the goodness value of a node selected is increased via $P_{nd} = P_{nd} + r\,(1 - P_{nd})$, $0 < P_{nd} \leq 1$ and the goodness values of the other nodes $f \neq n$ are decreased via $P_{fd} = P_{fd} - rP_{fd}$ so that the sum of goodness values always remains 1. The decision of the PI-container is taken by drawing from the respective probability distribution.

The local traffic statistics contain the sample means and variances computed over the trip times experienced by the measurement PI-containers during a moving observation window. They are updated via exponential smoothing. Both types of information give a local view of the global state of the PI network. Dispatchers can use the traffic statistics to set a reasonable delivery date, while the routing table guides the PI-containers through the network.

3 Technical Aspects of Blockchains for PI

A prototype for a standard PI-container called M-Box was developed in project MODULUSHCA (modular logistics units in shared co-modal networks) funded by the seventh Framework Programme of the European Commission. Fifteen partners from research, logistics business, postal business, and FMCG industry participated in this research project in close coordination with North American Partners and the international PI Initiative (Landschützer et al., 2015). The three leftmost parts of the function tree in Fig. 2 depict the function tree employed by Landschützer et al. (2015). In their design, Landschützer et al. (2015) assume the presence of a central control system, to which a PI-container would respond by providing its identity, contents, and location, and which on this basis would make the routing decisions. To move to a decentralized environment using blockchain technology and autonomous decision-making, we build on this design and ideas brought forward in Sallez et al. (2016) and add autonomous routing as a fourth aspect in Fig. 2, including the ability to select and pay PI-nodes, PI-movers, and PI-handlers.

To support the functions for the interaction with SC, each PI-container would have a unique address on the blockchain and a key pair through which it could effectuate payments in time, money, and emission tokens using a wallet where the funds are provided by the organization that wants to use the PI. In order to provide

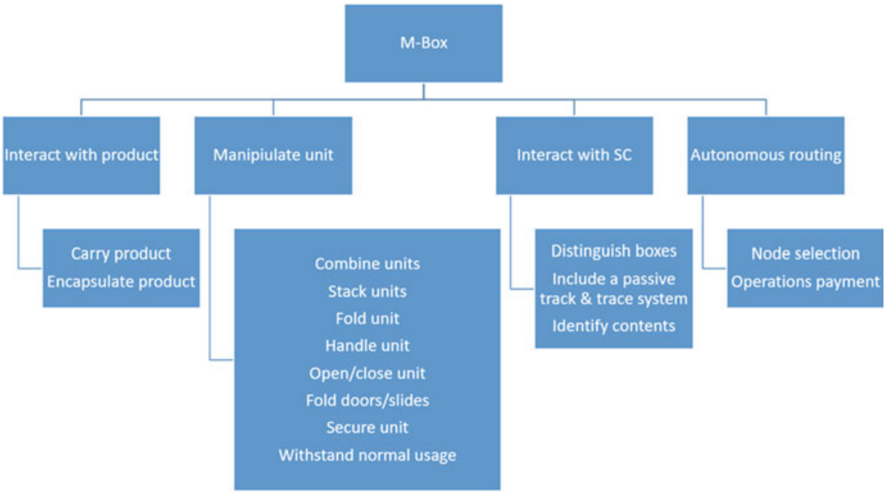

Fig. 2 Key functions of the M-Box, adapted from Landschützer et al. (2015)

maximum openness, the blockchain should be a public permissionless blockchain such as Ethereum, and the tokens used for paying for the service could follow the ERC-20 standard.

To support track and trace, a PI-container has sensors for determining the location, for recognizing operations done, and for sensing the environment (e.g., the temperature, humidity, etc.). The measurements supplied by these sensors will be the input for the routing decisions based on the information in the routing nodes shown in Fig. 1 and the oracles to the smart contracts that control the interaction of the PI-container and the PI-nodes, PI-movers, and PI-handlers that perform actions on the PI-container and get paid for that by the PI-container. PI-nodes, PI-movers, and PI-handlers have wallets too, and the smart contracts act as notaries which hold funds, collect oracle messages, and effectuate payments.

As the routing tables can become large and are updated frequently, they should not be stored on the blockchain. They also should not be stored in a central cloud storage as this would introduce a central point of control and failure and a potential performance bottleneck. Instead, we choose an approach based on edge computing (Yu et al., 2017). In the edge computing architecture, edge computing servers located close to the data origins are introduced that take over the computational load from central cloud servers. In this way, computationally weaker edge/cloudlet servers can increase quality of service through lower latency by performing real-time data analysis and action response and communication/messaging. The central cloud servers would perform long-term analytics and storage and data integration. We propose to store the routing tables associated with a PI-hub on edge/cloudlet/servers to allow fast update and data retrieval by the PI-containers and the logistics service providers, while the system-wide reporting and support for the governance of the PI organization is provided by central cloud infrastructure.

4 Conclusion

This chapter addresses the challenges of modern logistics and transport supply chains to reach logistics sustainability at a global level by addressing economic, environmental, and social dimensions. Technological innovations like blockchain and related optimization techniques are of particular importance. To fulfill the presented requirements of the PI, collaboration is a prerequisite that requires tailored supply chain solutions.

First, this chapter provides an overview about the foundations of the PI and the related historical context, the main characteristics of the PI, the state of the art that is relevant from a planning and management perspective, the importance of collaboration, and the potential contribution to sustainability.

"Insights from the top management" are presented based on five questions that are of importance if the PI meets blockchains from a top management perspective of logistics service providers. The provided answers highlight that the support of digitalization and data management is an incubator to make traditional logistics flows more efficient, but the movement of physical goods will always be the core of the service. To achieve the benefits of new technologies, like blockchain, they would have to be used by all acting parties, and customs, port authorities, or banks must comply with the new technology. The PI may require changing the business models of the involved supply chain partners. The owner of cargo might be more relevant and the typical forwarders might have to rethink their business models. Data sharing and standardization of transport processes and interfaces (digital and physical) seem to be major challenges for the implementation of the PI. Megatrends like sustainability, digitalization, and urbanization are the drivers for structural changes of the entire logistics and transport supply chains, e.g., logistics concepts for urban and rural areas and shift between means of transport.

Second, based on the open distributed nature of the PI, it is natural to propose a blockchain architecture to support its operations, e.g., conceptional designs describe already how PI-containers are blockchain tokens that are storing identity and movement data. Shortcomings of these proposed solutions are presented, e.g., algorithms for routing and task allocation are not specified. We propose another architecture involving blockchain technology to overcome the presented shortcomings. This innovative architecture is presented in detail, i.e., an AntNet type of algorithm is proposed for the routing of PI-containers through the network in a decentralized fashion.

Finally, technical aspects of blockchains for PI are addressed. Contrary to the assumption of a central control system, to which a PI-container would respond, we describe a decentralized environment using blockchain technology and autonomous decision-making.

The presented blockchain architecture for PI based on ant colony optimization is a promising further research direction and will contribute to the implementation of the PI.

Management Perspective on PI Meets Blockchain: Insights from the Top Management

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The following five guiding questions will address different elements that are of interest if the PI meets blockchains from a top management perspective in the field of logistics services.

> How will the PI change the relationship, roles, and positions between the supply chain partners? Who will be more important, who will be less important, and who will be added?

Besides the physical movement of goods, the traditional competitive foundations of the logistics and forwarding industry are the dissymmetry of communication and information and the balancing of supply and demand of

(continued)

transport capacities between shipper and customer. All these services are tackled by the concept of the PI. Key success factors are transparency, data visibility, and the standardization of transport facilities. The role of intermediaries will incrementally become obsolete, and will be replaced by relevant data platforms and data interfaces. The development toward the PI is ongoing, and fragments of it have already started to be implemented like automated container terminals, automatic booking platforms, and algorithms or closed general cargo systems and networks that are part of the service offering of big players in the logistics industry. The result is that such players will strengthen their market positions, and the standing for mid and small players will become tougher. One of the major challenges toward the further development of the PI will become if and how to join and integrate these fragments. Independent of size, the logistics background and ownership of assets in the logistics chain will continue to be crucial. Outside scalable and standardized logistics flows, the know-how to plan, realize, and execute complex and robust logistics flows will remain essential to support special demands and problem-solving that will always be present. The support of digitalization and data management is an incubator to make traditional logistics flows more efficient, but the movement of physical goods will always be the core of the service.

What do you think about blockchain technology as a game changer in legal aspects between certain stakeholders to strengthen the PI approach?

I do not see blockchain as game changer. There was an international hype on various applications of the blockchain technology in transportation and logistics over the past few years. For example, we have seen and tested blockchain used in international sea freight to substitute the bill of lading and the paperwork involved in such transports. The technology to digitize this traditionally manual documentation is available and already working, but the acceptance by all concerned parties is not there. To achieve its benefits, blockchain would need to be used by all acting parties, and customs, port authorities, or banks must comply with the new technology. As there are ways to speed up and digitize transport documentation without the complex and energy demanding concept of blockchain, there is no real need to adapt among all affected parties.

Who is the winner of collaboration in logistics?

If the concept is applied correctly, all aspects of the logistics chain should benefit. I see the highest advantage for those parties that are owners of cargo somewhere along the chain. They can collect appropriate data and can avoid

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delays or high stock levels (supply chain bullwhip effect) if the concept is working. The likelihood that only one global standard would be agreed on is unrealistically low. Therefore, I do not see only one winner or only one provider of the PI as the final outcome. In the first run, some players or groups will more probably develop different but broadly accepted standards that can be used and that might be in competition. These players will develop from already existing companies or networks, but I will not guess whether they will have their background more in logistics or e-commerce/IT. The business model of typical forwarders will prove problematic and will be stuck in the middle. They will most likely be the losers of this collaboration.

What are the biggest obstacles of implementation of the PI?

The basic idea requires full transparency and free flow of information and data. Success on the logistics market is more based on data and information than in other industries. Shippers, forwarders, carriers, and other agents base their market power on their control of information and are very reluctant to share data. The required standardization of transport containers and interfaces (digital and physical) is also a major challenge. High investments will have to be made according to tough economic investment decisions requiring a clear and profitable business model. Economical egoism and the run for competitive advantages to safeguard business models is the biggest obstacle. The development can only be aimed step by step, and first existing and working concepts will have to prove the feasibility and establish industry standards that might be later integrated and expanded. In the long run, there is enough space for various standards and systems to coexist. Major industries or product groups might have their own variation of the PI.

What are the main challenges in logistics and supply chain management within the next 10 years?

Structural changes of the entire logistics setup are ongoing and will take place. Megatrends like sustainability, digitalization, or urbanization are the drivers behind such developments. New ways to supply logistics needs in cities must be created that comply with the flexible and increasing demand from e-commerce and with high ecological requirements at the same time. A higher level of distinction between logistics concepts for urban and rural areas with clear interfaces and cross-dock facilities in between will develop. Another development is the expected shift between means of transport. Again, ecological requirements need to be considered, but capacity issues are simultaneously becoming increasingly important. For example, belly capacities in airfreight have dropped dramatically since Covid-19, and it is questionable if they will

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ever fully recover. Last but not least, the growing lack of truck drivers is an underestimated and unsolved risk that has the potential to collapse international, especially European, transports and supply chains.

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Collaboration in Humanitarian Operations in the Context of the COVID-19 Pandemic

Milad Keshvari Fard and Felix Papier

1 Humanitarian Operations

In 2019, more than 396 natural disasters occurred, affecting 95 million people and leading to a cost of USD 103 billion. The frequency and cost of these disasters were higher than the average of the last 10 years.[1] In the same year, the number of displaced people in the world, including refugees and asylum seekers, reached 80 million, a record number which is twice as high as the average of the years 1990 to 2010;[2] and yet this situation is before the disastrous year of 2020. Such ever-growing needs for aid have led to a growth in humanitarian organizations (HOs) operating on the ground.

For example, after the 2010 Haiti earthquake, between 3000 and 10,000 aid organizations engaged in aid delivery (Kristoff & Panarelli, 2010). In 2019, the United Nations (UN) received more than USD 18 billion in donations for humanitarian aid, which benefited more than 117 million people around the globe (see footnote 2). It is obvious that this enormous collective effort requires efficient logistics and supply chain processes, from the sourcing to the delivery on the ground. This is the field of *humanitarian operations and logistics*.

Humanitarian aid and consequently its operations are often categorized into disaster relief and development programs. While the former consists of preparedness and response activities to mitigate the effect of a crisis, the latter focuses on

[1] https://reliefweb.int/sites/reliefweb.int/files/resources/ND19.pdf

[2] https://www.unocha.org/sites/unocha/files/2019OCHAannualreport.pdf

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enhancing the welfare of beneficiaries, building local capacities, and improving resilience in local communities through longer and more stable operations.

According to Van Wassenhove (2006), between 60% and 80% of the total costs of any humanitarian aid goes to logistics; therefore, humanitarian operations have received significant attention in recent years. The attention toward this field started after the 2004 Asian tsunami, when despite the huge donor supports, massive inefficiencies were observed and HOs were heavily criticized. Since then, HOs started to systematically build competencies in logistics, operations, and supply chain management, and a growing community of academics has begun to perform research on humanitarian operations (Besiou & Van Wassenhove, 2020).

While humanitarian operations share some common elements with traditional and commercial operations, there exist a number of fundamental differences between the two. First, HOs do not seek to generate profit as their ultimate goal; instead, their objective is to enhance the living conditions and welfare of the beneficiaries. Therefore, HOs follow objectives such as equity, effectiveness, and efficiency to plan their operations and evaluate their performance. Second, HOs rely on donations and grants from public and private donors to finance their operations. Relying on donations, however, poses many challenges to HOs; usually HOs are underfinanced, which forces them to prioritize their engagement. Moreover, the amount and type of donations and the timing of receiving these donations are not known with certainty in advance, rendering the management of humanitarian operations particularly difficult. Furthermore, donors may typically choose to *earmark* donations, i.e., to assign them to a certain purpose or region. While this possibility is appealing for donors and can increase the amount of funds raised, it poses severe constraints on the operational flexibility of the HOs and in allocating their resources to the most urgent operations (Aflaki & Pedraza-Martinez, 2016). Third, humanitarian operations are conducted under highly uncertain conditions; crises vary in nature, size, and requirements, making the needs highly unpredictable. Such uncertainty also exists on the supply side, given the frequent absence of formal contracts between the HOs and suppliers, lack of qualified suppliers, and scarcity of aid items in the aftermath of crises. Uncertainty of the operational environment, especially after disasters (e.g., damaged roads or mal- functions in communication systems), as well as the short implementation time, further complicates the operations. In addition, humanitarian organizations often operate in insecure environments with significant security challenges, are composed of a complex landscape of stakeholders, have difficulty in hiring and retaining talented employees, and are faced with high levels of corruption (Wagner, 2020; Berenguer et al., 2020; Keshvari Fard et al., 2021).

In order to model the humanitarian operations, Lu et al. (2016) adapted the well-known *Supply Chain Operations Reference Model (SCOR)* from commercial operations to humanitarian operations. The *humanitarian SCOR* model has four *level 1 processes*: (I) PLAN, (II) RAISE and SOURCE, (III) STORE, and (IV) DELIVER. See also Wagner (2020) for a detailed discussion of the humanitarian SCOR model. The process *PLAN* comprises all tasks related to identifying needs, planning missions, and achieving *disaster preparedness*. Preparedness activities include, among others, estimating the likelihood of each type of disaster, hiring and training staff, pre-positioning material and supplies, and securing suppliers and transportation capacity (Van Wassenhove, 2006). The process *RAISE and SOURCE* corresponds to all activities related to procuring and receiving materials and supplies as well as managing suppliers and service providers. We also include in this step the important activity of fundraising which provides indispensable resources for humanitarian operations. The process *STORE* comprises the storage of supplies and assets in the right locations. In particular for disaster relief, the immediate availability of aid items and operational assets is a key challenge. Finally, the process *DELIVER* comprises the transportation and distribution of supplies, including local delivery and management of personnel, equipment, and vehicles. See, for example, Gralla and Goentzel (2018). In Sect. 2.4, we use the humanitarian SCOR model to further investigate the collaboration among HOs.

2 Collaboration in Humanitarian Operations

2.1 Overview

Many actors are typically engaged in humanitarian operations, especially after major crises. Although this provides a significant amount of financial, human, and material resources, without proper collaboration and coordination among these entities, inefficiencies and waste of resources would be inevitable. Consequently, there is increasing pressure from donors and governments on HOs to engage in collaboration with each other as well as other actors such as local governments, military, and private sector companies, in particular, logistics service providers (Jahre et al., 2007; Falagara Sigala & Wakolbinger, 2019).

The benefits of collaboration are well-known and comprise, for example, higher operational efficiency, better quality of service, faster learning from other organizations' practices, acquisition of new skills, risk sharing, higher public accountability, and conflict avoidance among different parties (see, e.g., Gazley (2010)). But there are also numerous obstacles that render collaboration in the humanitarian context particularly difficult. Actors are often considerably different in terms of purpose, skills and expertise, capacity, mandate, values, and organizational cultures. They may follow different agendas for their strategic and operational decisions, have varying degrees of autonomy, and consider different time frames for their missions. Under such heterogeneity, it may be difficult to find common grounds for collaboration (Balcik et al., 2010). Other impediments of collaboration include the threat of losing a core competency, lack of trust and transparency regarding the fair allocation of benefits, and lack of resources (Schulz & Blecken, 2010). Therefore, HOs with similar vision, mission, and internal policies have easier routes to collaboration. Willingness to share valuable assets (e.g., access to unique information, supply chain expertise, infrastructure) among HOs, especially when they are complementary, is another key predictor of the success of collaboration (Moshtari, 2016). Finally, mutual trust, reciprocal commitment, and information sharing are among the most cited success factors of collaboration.

2.2 Types of Collaboration

Collaboration in humanitarian operations can be categorized as vertical, horizontal, and diagonal collaboration.

Vertical collaboration concerns collaboration between upstream and downstream partners of a humanitarian supply chain, such as donors, fundraising entities, organizations with procurement, warehousing, and transportation capabilities, and last-mile delivery organizations. Often, vertical collaboration benefits from a *central chain coordinator*. A successful example of vertical collaboration is the *World Food Programme (WFP)*, which collaborates with more than 1400 organizations and coordinates the operations of all of its partners (Moshtari & Gonçalves, 2017).

Horizontal collaboration refers to collaboration among organizations that provide similar services or functions. This type of collaboration may involve HOs that are at the same time competing with each other on other parts of the value chain, leading to what is known as *coopetition*. An example of coopetition is the collaboration between the *Muslim Aid* and the *United Methodist Committee on Relief* in Sri Lanka's Trincomalee District, where the two organizations established joint offices and warehouses, and shared staff, vehicles, aid supplies, and logistical support, while working in coordination with their respective faith and community councils to collect funds and coordinate the mobilization of volunteers. A successful model for horizontal collaboration is the *service provider approach*, in which one organization takes the role of the "service provider" and the other partners act as "customers". This approach has several advantages for the HOs, in particular with regard to logistics-related activities. It provides economies of scope and economies of scale, and facilitates the consolidation of transportation and operations of multiple HOs (Schulz & Blecken, 2010). Although horizontal collaboration can significantly enhance the capacity, efficiency, and agility of humanitarian operations, there usually exist several barriers, such as the impediments mentioned in Sect. 2.1.

Diagonal collaboration occurs between organizations that are in different sectors and that are also at different stages in the supply chain, with no direct competition or relationship in terms of the service they provide. Humanitarian-business partnerships usually fall in this category and provide HOs with the access to resources, expertise, processes, and technologies of the private sector, and improve the professional and managerial skills of HOs (Cozzolino, 2012). An example is the partnership between MasterCard and *Save the Children* in developing the *MasterCard Aid Network* that is designed to streamline aid distribution even in the absence of telecommunications infrastructure.[3]

[3] https://newsroom.mastercard.com/press-releases/mastercard-transforms-aid-distribution/

2.3 The United Nations Model of Collaboration

To give a better idea of the scale and the players involved, in this part, we provide an overview of the largest and most organized humanitarian collaboration, supported by the UN. The UN has been implementing international collaboration mechanisms for humanitarian responses since 1991 through subordinate entities such as Inter-Agency Standing Committee (IASC), Emergency Relief Coordinator (ERC), and Resident Coordinators (RC) for each country. In 1998, the UN established the *Office for the Coordination of Humanitarian Affairs (OCHA)* to further coordinate humanitarian actions among different actors to achieve timely decision-making and effective disaster preparedness and humanitarian response. OCHA alerts the affected population and HOs in the early stages of a disaster or even before its occurrence. It provides a comprehensive picture of overall needs and prioritizes actions, ensuring that assistance and protection reach the people who need it most. To that purpose, OCHA engages with a diverse set of actors to achieve a common understanding of the humanitarian context and a collective plan for the response. These actors include UN entities, the Red Cross/Red Crescent Movement (IFRC, ICRC), national and foreign militaries, local and international NGOs and private sector companies, faith-based organizations, and many more. OCHA assembles and mobilizes the resources, plans the operations, and coordinates the actions of hundreds of different actors that collaborate vertically, horizontally, and diagonally.[4]

In 2005, the UN introduced the *cluster approach*,[5] with the objective to bring together all actors relevant to certain key activities of humanitarian aid, such as logistics, health, or food security. A cluster lead is assigned to each cluster to coordinate the actions within the cluster. The goal of the cluster approach is to enhance preparedness and response capacity in humanitarian crises, as well as to provide clear leadership and accountability. Figure 1 demonstrates the UN's 11 clusters.

These clusters can be activated in case of a major sudden-onset crisis, or as a result of a natural disaster or conflict, that requires a system-wide mobilization of resources.

The Logistics Cluster Considering the importance of logistics in humanitarian operations, the logistics cluster is one of the most important clusters. WFP was chosen as the cluster lead due to its expertise and infrastructure in the field of humanitarian logistics. The role of the logistics cluster is, among others, to fill logistical gaps, to alleviate bottlenecks, to prioritize logistics investments, to collect and share information, to coordinate ports and corridor movements with the objective of reducing congestion, and to provide guidance on customs issues. Obviously, WFP cannot handle alone all of these tasks for the logistics cluster. To that purpose, it has been engaging in partnerships with governments, NGOs, and the private

[4] https://www.unocha.org

[5] https://www.humanitarianresponse.info

Fig. 1 UN clusters with the associated cluster lead(s)

sector. For example, the Boston Consulting Group, TNT, Citigroup, Unilever, DSM, the Vodafone Group Foundation, and the Bill & Melinda Gates Foundation are among WFP's partner organizations (Quinn, 2010).

A key initiative of the cluster that facilitates the collaboration of different members is the *Logistics Cluster Preparedness Platform*.[6] This global platform shares updated, processed, and relevant information with different actors and associates of the cluster. This platform is a dynamic data collection tool that integrates real-time reports with images, mapping, and analytics to enhance decision-making for both preparedness and response phases.[7]

Logistics Emergency Teams One of the main entities working for the logistics cluster is *logistics emergency teams (LET)*. LET is a unique and successful model of partnership between humanitarian organizations and the private sector. Through the LET, four of the largest global transportation companies, Agility, UPS, Maersk, and DP World, work together to support the logistics cluster. The LET continuously holds more than 100 trained volunteers on standby in different countries, who are

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[6] https://www.arcgis.com/apps/MapSeries/index.html?appid=bc6ab99b622a4ef799b0cd0ad869b090

[7] https://logcluster.org/preparedness

ready to be deployed upon the request of the WFP within 48 h.[8] LET has a steering committee, where they convene regular meetings, together with the representatives of the logistics cluster.[9]

The LET contributes to the logistics cluster in several ways such as providing logistics experts (e.g., warehouse managers), logistics assets (e.g., trucks and warehouses), and logistics services (e.g., airlifts) (Cozzolino, 2012). It also develops internal knowledge for HOs (e.g., through workshops) and assists agencies and governments in improving their preparedness for humanitarian crises. In that regard, one of the main contributions of the LET are *logistics capacity assessments (LCAs)* for different countries. LCAs are formal evaluations containing information on the region's logistic infrastructure such as roads, customs, airports, bridges, etc. As of 2019, the LET has performed LCAs for more than 100 countries and identified the overall emergency response strategy and execution, support for contingency planning activities, preparation of emergency response plans, and measures to improve the overall response time and operations costs.[10]

Case 1: LET Intervention After the Flooding in Northern Peru *In March 2017, massive flooding struck northern Peru. The flood was the worst in more than 50 years; more than 125,000 houses were destroyed, leaving nearly 200,000 people homeless. Approximately 2500 km of roads were destroyed, and the main roadway from Lima to the affected northern regions of the country was blocked. The LET supported the Peruvian government in its response to the flooding. DP World took the "on the ground" leadership role in coordinating with the Ministry of Production and the Ministry of Defence teams to provide logistics support. Agility and UPS donated local trucking support and moved more than 500 tons of donated relief items from Callao to government consolidation facilities. DP World donated port storage and processing space in the port of Lima to enable the efficient processing, loading, and storage of cargo awaiting transportation to the north of the country. DP World also worked with its ocean carrier partners to provide free shipping of relief materials to the northern part of the country.*[11]

2.4 Collaboration Along the Humanitarian SCOR Model

In this part, we discuss collaboration among HOs and its implications in all phases of the humanitarian SCOR model.

[8] https://logcluster.org/logistics-emergency-team

[9] LET Annual Report 2018.

[10] LET Annual Report 2019.

[11] LET Annual Report 2017.

Collaboration in Planning (PLAN)

According to UNDP, spending 1 dollar on preparedness activities and reducing people's vulnerability could save around 7 dollars during disaster response.[12] Cost-effectiveness, as well as other objectives, has forced HOs to invest in preparedness and planning activities. Collaboration with other actors should be established at this phase, as it would allow for a more timely, effective, and efficient response, compared to ad hoc collaborations. For example, in periods of normalcy, the UN clusters continuously conduct tasks such as developing relationships with local authorities, establishing emergency supply chain preparedness, and identifying evacuation plans specific to each region.

A successful collaboration planning should go beyond verbal agreements; formal contracting and mutual framework agreements can result in better collaborations (Van Wassenhove, 2006; Berenguer et al., 2020). Moreover, similar to the cluster approach, having a central coordination entity and clear cooperation mechanisms are mandatory for successful collaboration. These mechanisms should define the responsibility of each actor, develop strategies to overcome unpredictable issues during relief operations, and allow other HOs to join the collaboration.

HOs should also adopt a strategic approach toward building trust in the preparedness phase. To that purpose, HOs have to invest in developing relationship management capabilities, such as coordination, communication, and bonding skills (Moshtari, 2016). This would also facilitate the exchange of information and communication of IT systems, which is vital for a successful collaboration. Different actors should accumulate their knowledge and information about the field in a central platform (see, e.g., the Logistics Cluster Preparedness Platform discussed in Sect. 2.3).

Consequently, any missing data and information should be identified and collected in advance of crises. An example of data that is crucial for humanitarian operations is digital maps of underdeveloped regions. The *Humanitarian OpenStreetMap Team*[13] is an initiative which provides open mapping, to which HOs and volunteers can contribute in building accurate maps for vulnerable areas.

Case 2: Earthquake Response Workshop in Bangladesh *Bangladesh is particularly vulnerable to natural hazards such as earthquakes, flooding, and tsunamis. Its capital Dhaka is one of the most densely populated cities in the world, and an earthquake in this region could lead to a high number of casualties. In August 2019, more than 100 humanitarian experts gathered in Dhaka for a 3-day Earthquake Response Workshop to build collective disaster preparedness. Jointly organized by the Bangladesh Ministry of Disaster Management and Relief, the WFP, and the UN. The workshop consisted of a disaster simulation that placed humanitarian workers in a real-life scenario. Participants gained a better understanding of how different types of disasters impact Dhaka, and how to mitigate this impact. Through the*

[12] http://hdr.undp.org/sites/default/files/2015_human_development_report.pdf

[13] https://www.hotosm.org

workshop, participants examined and simulated different supply chain operations during a potential urban earthquake, identified bottlenecks and gaps, and designed and fine-tuned their response plans to such an event. Each team's operational plan was evaluated by a panel of government officials who oversaw and coordinated the country's overall emergency response.[14]

Collaboration in Sourcing and Funding (RAISE and SOURCE)

Donors usually allocate funds according to the stand-alone performance of the HOs. This leads to competition of HOs over funds and media attention (Nagurney et al., 2016), and discourages collaboration. Earmarked donations can further exacerbate the situation. One solution for this is to have a central agency responsible for the collection of donations and their allocation to different HOs during humanitarian crises (Eftekhar et al., 2017). Nonetheless, with a strategic fundraising attitude, even competing HOs can join forces to raise funds more effectively. *Alliance Urgences*[15] is an example for such a collaboration that unites six HOs in France that collaborate through joint donor contact, fundraising, and budget allocation. Pooled humanitarian fund is another mechanism that allows for better collaboration in the funding stage.

Lack of trust and transparency is a key barrier to collaborative fundraising. Several HOs have recently started adopting blockchain technology. Blockchain-based platforms for donations can enhance swift trust among different actors, leading to higher collaboration among HOs, and enhanced supply chain resiliency (Dubey et al., 2020). Coordination among large donors such as governments about the destination of funds can also facilitate the collaboration among HOs.

Collaboration is also of strategic importance for sourcing, in particular for smaller HOs. Joint purchasing between multiple HOs to combine expertise as well as purchasing volume is an effective way to manage purchasing of complex products and services. Joint purchasing of items results in lower purchase prices, improved supplier selection processes with higher product quality, and long-term contracts with suppliers which reduces the risk of supply shortage (Schulz & Blecken, 2010). Participating in such partnerships can also strengthen HOs' visibility among donors and the general public. An example of joint purchasing is the *COVID-19 Emergency Service Marketplace* of the UN (see also Sect. 3).

Case 3: Country-Based Pooled Funds (CBPF) and Central Emergence Response Fund (CERF) *CBPFs are multi-donor resources dedicated to countries with ongoing humanitarian crisis (18 countries as of 2021). With these funds, hundreds of local and international HOs could finance urgent projects without having to raise funds on their own. In 2020, the CBPFs received USD 891 million, which were allocated to 682 partners for 1339 projects in the 18 different countries. International HOs received the largest share of the funds (42%), followed by*

[14] https://www.wfp.org/news/preparing-unexpected-humanitarians-build-their-capacity-earthquake-response

[15] https://www.allianceurgences.org

national HOs (33%), and UN agencies (22%). CERF, on the other hand, is a central, non-earmarked fund to satisfy the most critical needs worldwide. With a USD 1 billion annual target, CERF allows OCHA to immediately fund operations right after disasters, to scale up activities when a situation deteriorates, and to maintain critical operations when other funding falls short. To allocate funds to the most urgent projects during emergencies, the UN agencies and other HOs jointly assess and prioritize the needs and apply for CERF/CBPFs. Funds are immediately released if the proposals meet the previously developed criteria. This collaborative process allows for quick, flexible, efficient, and effective financing of humanitarian operations.[16]

Collaboration in Storage (STORE)

Collaborative storage is frequent among large HOs. In this case, several HOs share a network of common warehouses and storage facilities for aid items and certain equipment (e.g., vehicles and generators). The benefits of shared storage in humanitarian operations are similar to those for the private sector, including decreased fixed costs by consolidating facilities, equipment and personnel, access to a wider network of warehouses, and therefore, larger area coverage, lower transportation costs, and shorter lead times for aid delivery (Schulz & Blecken, 2010).

Some items such as water, tents, medicine, blankets, chlorination tablets, and protein biscuits are particularly important in relief operations. Shared storage for these items is particularly effective when combined with joint purchasing, such that HOs use the same material and supplies. In such case, HOs can go beyond sharing storage and also share inventories and equipment, leading to higher flexibility and reduced risk of stock-out.

Case 4: UN Humanitarian Response Depots (UNHRD) *Managed by WFP, UNHRD serves 86 partners including UN agencies, governments, and NGOs. The core function of UNHRD is to provide warehousing, inspection, and handling of prepositioned relief items free of charge for its partners. UNHRD runs a network of six humanitarian support hubs located in Italy, Ghana, United Arab Emirates, Spain, Malaysia, and Panama. The location of each hub provides easy access to airport, port, and road systems, allowing response times of 24–48 h in case of a disaster. The hubs support dry storage, cold chain storage, special storage for dangerous goods, and storing a wide range of items from refrigerated medicines to armored vehicles. In addition to storage, the UNHRD provides a range of related services such as procurement and transportation. Through long-term agreements with a wide range of suppliers for core products as well as transportation providers, the partners do not need to go through a long tendering process for each order. Due to the consolidation effect, the procurement of items and their transportation from suppliers to the field via the warehouses can happen at a lower cost and in a shorter time. Interchange of stock or* stock loans *is also common among the partners of*

[16] https://www.unocha.org/our-work/humanitarian-financing

UNHRD, where HOs can borrow the stock of other organizations in case of urgent need and replenish it later. UNHRD encourages its partners to keep stock that meets common standards in unbranded condition, to allow the borrowing organization to brand it with its own logo before dispatching.[17]

Collaboration in Aid Delivery (DELIVER)

Aid delivery is the final stage of a humanitarian supply chain. Geographical dispersion of beneficiaries and difficulties of accessing them, the diversity of logistics requirements, reliability of available information, and security concerns are some of the issues that render this step particularly challenging. In relief operations, the urgency and criticality of aid delivery brings even higher attention to the last mile delivery, and collaboration plays a particularly important role in this step.

Collaboration requires coordination. The absence of organized coordination among different actors during relief operations not only results in inefficient use of resources but also leads to unnecessary congestion and chaos, worsening the situation by delaying the aid operations. In case of large disasters, local governments with the help of the UN are usually the main coordinators, controlling the entry and intervention of actors and coordinating different activities (Van Wassenhove, 2006). Collaboration is particularly effective if it involves HOs with different resources and specializations, such as vehicles, drones, doctors, and relief items. For example, during a large-scale crisis, up to thousands of actors from all of the 11 UN clusters with different competencies in logistics, nutrition, healthcare, etc., collaborate to deliver aid.

Collaboration in humanitarian operations highly depends on effective information sharing and re liable IT platforms that are accessible to many actors. Having cloud-based IT solutions and using mobile devices for aid workers significantly enhances the efficiency of operations, as it provides HOs with improved data collection as well as real-time and optimized decision-making.

Case 5: The Relief.iO Platform *In 2017, the SAP 1BL venture Relief.iO was launched. The venture offers a robust collaboration platform to enable stronger collaboration between humanitarian stakeholders such as HOs, governments, and the private sector. The platform provides a mobile app for activity planning and collaboration among HOs; HO workers in the field can report the needs, accompanied with GPS information and pictures. The app also uses machine learning tools to inform the field workers about similar activities by other HOs, and allows to connect with staff of those HOs. Moreover, Relief.iO uses a machine learning-based tool to support the coordination and reporting activities. For example, it allows to read the reports from different HOs in various formats, understand and extract the required data, correct wrong data and even fill missing data, and finally consolidate them into a single report. Relief.iO also allows establishing a*

[17] https://unhrd.org/about-us

disaster relief supplier network. Real-time supply chain optimization techniques are used in the background to improve the aid efficiency.[18]

3 Learnings from the COVID-19 Pandemic About Collaboration in HOs

Mark Lowcock, Head of OCHA, writes in December 2020: "The picture we're painting this year is the bleakest and darkest perspective on humanitarian needs we've ever set out".[19] The COVID-19 pandemic has affected the populations and economies in many countries, with more than an estimated 134 million people infected by the novel coronavirus and 2.9 million related deaths by April 2021. The pandemic has also led to a global decline of economic activity in 2020 in the order of 4–6%.[20]

The COVID-19 pandemic has put many humanitarian supply chains to its limit, and has forced actors to rethink their operations and collaboration. Many organizations had to adapt by improvising new operational processes and by rethinking their collaboration with other actors. We believe that much can be learned from this period and some of the crisis adjustments may be maintained for the long term. In this section, we review some of the impacts that the pandemic has had on humanitarian operations and how HOs reacted to them.

3.1 Surge and Shift in Humanitarian Need

The economic and political consequences of the pandemic have led to a surge in humanitarian needs. In December 2020, OCHA estimated that 235 million people worldwide were in need, representing a 40% increase in humanitarian need compared to the previous year.[21] The pandemic also led to a shift in the priorities of humanitarian missions. For example, the displaced population, more than 80 million persons globally, of which many live in camps or camp-like settings, have substantial vulnerabilities during the pandemic, and their protection against the disease requires additional activities such as providing personal protective equipment and material for basic hygiene. In April 2020, 68% of HOs reported a reallocation of resources to missions related to the fight against COVID-19.[22] Finally, the geographic distribution of need also shifted.

[18] https://relief.io

[19] https://abcnews.go.com/Health/wireStory/pandemic-fan-surge-humanitarian-2021-74474230

[20] Report 'Global Economic Effects of COVID-19 - Update on 10 February 2021', Congressional Research Service, 2020.

[21] https://abcnews.go.com/Health/wireStory/pandemic-fan-surge-humanitarian-2021-74474230

[22] Report 'COVID-19 Impact on Humanitarian Operations', ACAPS, 2020.

The surge and shift in the demand for humanitarian aid forced many HOs to reconsider their planning and prioritization of missions, and to reallocate resources to new countries and new activities, while reducing their engagement in others. This is a particularly difficult task and requires building new capacities and competencies and relocating supplies and personnel. Earmarked donations render the adjustment of operations to the pandemic particularly complex. Changing the prioritization of missions requires a careful assessment of the global impact of the decisions. The effects of a reduced engagement in some missions can have dramatic consequences. For example, it was estimated that a 15% reduction in the vaccination activity against measles would lead to more than a quarter of a million related childhood deaths, potentially exceeding the impact of COVID-19.[23]

A key learning from prior pandemics is that rapidly changing needs should be met with a strength ening of the local deployment of aid activities, which leads to more agility and also more relevance for local needs. HOs should seek to decentralize decision-making to local *emergency response centers*. Konyndyk et al. (2020) suggest an *area-based coordination* of humanitarian operations compared to the more common cluster-based coordination. Under an area-based approach, coordination is performed locally by involving all relevant actors of the same area. This approach is more holistic and human-centered than the cluster approach, and consequently allows better alignment of humanitarian actions with local needs and more autonomy for frontline actors. Local emergency response centers should also work closely with local governments and public authorities to build buy-in.

Uncertainty of Donations for Humanitarian Aid

The COVID-19 pandemic has not only affected aid-receiving countries but also aid-providing countries in the developed world. The economic impact and the need for adapting national health systems and economies to the pandemic has led some public top donors to reconsider their commitment to funding humanitarian aid. For example, in July 2020, Global News reported that overall donation commitments from the largest governments has been only USD 16.9 billion, representing a drop of 30% compared to the commitments in 2019 at the same time of the year.[24]

The sputtering arrival of donation commitments and the general level of uncertainty in the first part of the COVID-19 pandemic has also raised doubts about the certainty of the commitments made. This doubt led to additional uncertainty, and consequently to more difficult operational planning. HOs hesitated to commit resources to some of their planned missions, waiting for the confirmation of donations. This led to a delay in execution and even to cancellations of humanitarian missions, even if donations finally arrived as planned.

Protecting against donation uncertainty is difficult. On the upstream side, HOs can prepare by keeping a buffer of financial resources available (see, e.g., Keshvari Fard et al. (2019)) and by being transparent on the prioritization of their missions. On

[23] https://science.sciencemag.org/content/369/6501/261

[24] https://globalnews.ca/news/7203980/coronavirus-humanitarian-aid-drops

the downstream side, HOs may seek to build agile operations and to postpone key decisions as much as possible, for example, through redesigned logistics processes and flexible supplier contracts.

Restrictions for International Transport and Logistics

Right from the onset of the COVID-19 pandemic, many countries restricted the movement of goods and people. By April 2020, 145 out of 195 countries had put in place border closures and 141 countries had at least partially suspended international flights. These restrictions were particularly harmful to humanitarian operations, because of their international nature and the moderate budget available: 79% of HOs reported restrictions on their international movements and 22% reported limitations on the import and export of their humanitarian supplies. As a consequence, HOs had to reduce their activities. 7% of HOs had to stop all operations and 13% had to limit their operations exclusively to lifesaving activities.[25]

Some HOs decided to switch to activities that do not require complex logistics, such as providing cash-based assistance. Another strategy to counter the effect of limited international movements is to rapidly build local capacity and skills. Building local capacity includes recruiting and training local staff, which reduces the need for international movement, reduces exposure of foreign aid workers, and helps building local buy-in. 43% of HOs reported using this strategy during the COVID-19 pandemic.[26]

In May 2020, the European Union (EU) put in place and financed the temporary *EU Humanitarian Air Bridge (EU HAB)*. Under this air bridge, the European Commission together with the EU member states provided dedicated air cargo and passenger capacity to maintain the flow of goods in the humanitarian supply chain, in particular to Africa. Any HO that requested transportation for humanitarian aid could apply to the services. In addition to the financing, the European Commission and the member states also provided diplomatic support for the organization of the dedicated flights. The *Humanitarian Logistics Network (Reseau Logistique Humanitaire – RLH)* and its member associations helped to coordinate the transportation by consolidating needs and transportation specifications. By the end of 2020, with a budget of only EUR ten million, EU HAB transported 1150 tons of cargo and 1700 humanitarian aid workers to more than 20 different countries.[27]

Since then, WFP has set up the *COVID-19 Emergency Service Marketplace*, an online platform for free cargo consolidation and transportation services of humanitarian supplies. The network provided air, sea, and ground transportation to many different countries and relies on eight global hubs (Guangzhou, Dubai, Liege, Kuala Lumpur, Addis Ababa, Panama City, Accra, Johannesburg). Wherever possible, the

[25] Report ‘COVID-19 Impact on Displaced Populations’, ACAPS, 2020.

[26] Report ‘COVID-19 Impact on Humanitarian Operations’, ACAPS, 2020.

[27] https://ec.europa.eu/echo/eu-humanitarian-air-bridge-helping-aid-reach-people-need-during-coronavirus-pandemicen

marketplace helped to consolidate cargo to allow for direct transportation from the source to the destination country.[28]

The two examples of the EU HAB and the COVID-19 Emergency Service Marketplace illustrate the necessity of collaboration among HOs during the pandemic. Given the many limitations and restrictions, individual HOs found it very difficult to ensure global transportation. A network of collaborating actors is much better suited to overcome the many obstacles resulting from the pandemic. In this network, every actor should contribute its specific competencies. In the case of EU HAB, the EU provided the political and financial support, while the RLH and other organizations contributed their competencies in humanitarian operations and their knowledge of the needs of the participating HOs.

Shortage of Essential Supplies

The outbreak of COVID-19 led to a severe shortage of essential items, such as personal protective equipment and medicine. This shortage triggered the emergence of several initiatives of collaboration, in particular in the area of procurement.

In the first half of 2020, the UN and the WHO created the *COVID-19 Supply Chain System*, consisting of a central supply chain task force to coordinate supply decisions, a supply portal and purchasing consortia to pool procurement of essential items, and a control tower for day-to-day coordination of the transportation from suppliers to the destination countries. The system provided access to a selection of 50 critical items such as personal protective equipment or diagnostics tools. Its objectives were to consolidate demand from different HOs (e.g., by aligning specifications and timing), to increase purchasing power by aggregating volumes, to ensure equitable allocation to different HOs and countries, and to provide efficient distribution, relying on the COVID-19 Emergency Service Marketplace (see above).[29]

In April 2020, the *Coalition for Epidemic Preparedness Innovations (CEPI)*, the *Global Alliance for Vaccines and Immunization (Gavi)*, and the WHO created the virtual *Global Covax Facility*, a pooled purchasing mechanism for COVID-19 vaccines.[30] Because of its experience with vaccine logistics, UNICEF served as a key distribution partner for the Global Covax Facility, ensuring global transportation, traceability and authentication of vaccines, and waste management. Covax concerned more than 90 middle- and lower-income countries that would not be able to individually secure access to COVID-19 vaccines. A global procurement platform helped securing production capacities for these countries. Allocation was based on peoples' needs rather than on a country's purchasing power. Developed countries and other large donors provided financial guarantees to vaccine manufacturers to invest into corresponding production capacities. Covax also

[28] https://emergency.servicemarketplace.wfp.org

[29] https://www.who.int/publications/m/item/COVID-19-supply-chain-system-requesting-and-receiving-supplies

[30] https://www.who.int/initiatives/act-accelerator/covax

established a continuous forecast on planned vaccine allocation volumes for each participating country, providing countries with planning stability to set up the necessary distribution logistics.

Management Perspective on Collaboration in Humanitarian Logistics

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What role does collaboration play in the humanitarian sector? Collaboration is essential as humanitarian organizations seek to maximize their efficiency and increase their footprint when carrying out their missions. Agencies in this sector collaborate in various capacities with similar organizations, as well as with actors in the private and public sectors to share knowledge, expertise, and resources to address societal issues in a comprehensive manner. The most successful humanitarian endeavors engage a multitude of players in complex collaboration with government agencies, philanthropic foundations, individual and corporate donors, service providers, and other humanitarian organizations. Collaboration in the humanitarian sector has been also a key element in the humanitarian response to the COVID-19 pandemic, where organizations leveraged existing partnerships to respond to increasing needs in a rapidly changing environment. These relationships had been cultivated over several years, at times decades, which enabled the humanitarian sector to mobilize rapidly and pivot during the unprecedented crisis.

What are the career opportunities in supply chain and logistics in the humanitarian sector and what are the skills needed? The sector offers operations graduates opportunities to apply their skill set in an alternate environment, merging the need to optimize operations with a humanitarian organization's mission and values. Available positions range in scope, from community-based to international work environments for applicants with backgrounds in supply chain coordination, purchasing and supplier management, warehousing and inventory management, and transportation. Complementary skills include experience in execution, leadership, and human resource management. Experiences in data analysis, optimization, and simulation are assets in these positions.

Recently, there has been an emphasis on optimizing processes and streamlining procedures to decrease operating costs and increase outputs. The sector has seen an accelerated shift in adapting more efficient solutions, such as working with external vendors or using new software to better manage inventory. As service delivery needs change, people in these positions require a high level of adaptability and creativity, and the ability to critically analyze their operations through the HO lens, which can mean the incorporation of ethical considerations into planning and execution. This enables agencies to

(continued)

alter their approaches to meet the needs of their target population. As the demand for humanitarian relief can increase exponentially in uncertain times, leaders with experience in crisis management and contingency planning are particularly equipped to help ensure the service delivery in a timely fashion.

Essentially, while supply chain roles remain similar across sectors, working for a humanitarian organization requires additional levels of analysis and planning to ensure that internal and external processes coincide with the humanitarian organization's values.

How do you expect the humanitarian sector to change in the post-COVID world? As the pandemic persists, the humanitarian organizations that have the capacity to respond to the increasing needs of their stakeholders by adapting their operating models, being flexible, and partnering with other organizations or sectors will continue operating. These agencies will expand as humanitarian needs and wealth disparity continue to grow, but they will also fill in the gaps left behind by organizations that have not succeeded in adapting to the digital age or that had to cease operating for other reasons. The humanitarian sector has experienced waves of consolidation in the past, typically associated with decreased funding. In those instances, the ones that survived had solid donor bases, diversified revenue streams, and the capacity to collaborate with different sectors to fulfill their mandates. Another aspect to consider is the emergence of social entrepreneurship that combines private and humanitarian sector operating models. While these models are not pervasive, their influence continues to grow and may impact how the humanitarian sector operates. These effects remain to be seen on a broad scale. To sum up, the humanitarian sector in the post-Covid world will be one of increased collaboration between the private, public, and humanitarian sectors, which at times may appear blurred with the advent of social entrepreneurship. The agencies that thrive in this changed environment will have a renewed focus on efficient service delivery, increased investment in digital transformation, social media presence, and revenue-generating activities.

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Logistics Challenges and Opportunities in Africa in the 2020s

Rose Luke and Jackie Walters

1 Introduction

Africa is globally recognised as one of the world's key growth areas (Excedea, 2020; Leke & Signé, 2019; Leke et al., 2018), with reasons for future opportunities cited as follows: the fast growth rate of many African markets (Excedea, 2020; Getachew & Tessema, 2020; Smith, 2020); the unprecedented population boom, with Africa having the world's youngest and fastest urbanising population, implying major increases in consumption (Excedea, 2020; World Economic Forum, 2020); increasing business consumption (Signé & Dollar, 2020); regional integration efforts such as the creation of the African Continental Free Trade Agreement (AfCFTA) which will become the world's largest free trade area (Hashi, 2019; Signé & Dollar, 2020); improved political stability and business environments (Signé & Dollar, 2020); a growing middle class and rapid progress in mobile and Internet penetration (Hruby and Rugo, 2020); and increasing industrialisation (Leke & Signé, 2019), amongst others. Significant opportunities thus exist for business in Africa.

2 Issues Affecting Trade in and with Africa

McKinsey predicts $5.6 trillion in African business opportunities by 2025, and it is suggested that if "Africa sustains and accelerates structural reforms, some believe the continent can emulate China's rapid rise of the last 50 years" (World Economic Forum, 2020). However, whilst Africa is the second largest continent, both in terms of land area and population (Excedea, 2020), it accounts for 17% of the world's population (about 1.3 billon people), but only 3% of its GDP (World Economic

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Forum, 2020); it lags behind in economic development. By implication, this affects the ability to trade with and in Africa.

Poverty remains a major impediment to trade growth and development in Africa. Whilst there is stability in growth in trade on the continent, it is estimated that only 18 of 48 countries have managed to achieve inclusive growth. Generally, the current growth rate is insufficient to achieve wide-scale poverty and inequality reduction (Getachew & Tessema, 2020). Fox (2019) asserts that much of Africa's growth does not result in poverty reduction because of high initial poverty, low asset levels and limited access to public services, which prevent households from taking advantage of opportunities.

Logistics infrastructure is still a major stumbling block to trade in Africa. This refers not only to transport infrastructure, including roads, rail, terminals, border facilities, intermodal facilities, ports, airports and pipelines, but also to power supply and communications infrastructure, without which logistics cannot function appropriately. It is estimated that, in sub-Saharan Africa, poor infrastructure reduced national economic growth by an estimated 2% and cut business productivity by as much as 40% (Tuggee in Smith, 2020). A lack of continental connectivity is a feature impeding intra-African trade, particularly as most railway lines were developed to connect hinterlands to ports on the east and west coasts, and where road and rail linkages exist, these are often in very poor condition.

The World Bank's *Ease of Doing Business* 2020 report indicates that it is still very difficult to conduct business in Africa. From a logistics perspective, measurements such as the ability to start a business, maintain a stable power supply, ease of trading across borders and enforcing contracts are some of the most critical. The report indicates that some African countries like Nigeria and Togo have shown significant improvements, but sub-Saharan Africa is still a weak performing area, with an average score of 51.8, below the OECD high-income economy average of 78.4 and the global average of 63.0. Compared to the previous year, sub-Saharan African economies raised their average ease of doing business score by just 1% point, whereas economies in the Middle East and North Africa region raised their average score by 1.9 (AUDA-NEPAD, 2020). The issue of *border crossings* is a major impediment to trade which, although recognised by the Southern African Development Community (SADC) Protocol on Trade in 1996 (SADC, 1996) (amongst similar findings in other regional agreements) as well as numerous research papers (as identified, amongst others, by Rodrigues (2011)), remains critical. Issues include cumbersome documentary and border compliance procedures (World Bank 2020a), unharmonised procedures and processes between countries, corruption at border posts and the lack of one-stop border posts, all resulting in delays and high costs.

Political instability and conflict remain a threat to Africa's ability to do business, where it is estimated that 18 of the states in sub-Saharan Africa are fragile or conflict affected. A further 13 states are small states with small populations, limited human capital and confined land space (Leke et al., 2018; World Bank 2020b).

Corruption remains a part of the business landscape in Africa (Leke et al., 2018). Bizimana (2020) asserts that the success of AfCFTA is severely threatened by corruption and "does not have anti-corruption provisions to promote integrity in customs and trade practices. According to the TI CPI (2018) and World Bank on Control of Corruption (2017), 48 out of 54 African countries score below 50% and 14 out of 52 score below 50% respectively". Gil-Pareja et al. (2019) assert that corruption may act as a barrier to trade, especially by increasing the cost; however, corrupt facilitators may facilitate trade in countries with strict regulations.

The *skills shortage* is considered to be a severe constraint to African trade (Maier, 2020). Globally, there is a major skills shortage (Hallett, 2016); however, Africa is likely to feel this more as the workforce expansion between now and 2030 is projected to be more than the rest of the world combined (Shango, 2019). "... 65% of African CEOs (global: 55%) said the skills shortage was preventing them from innovating effectively, while 59% (global: 47%) conceded that their quality standards and customer experience were being undermined. In addition, 54% (global: 44%) confirmed that they were missing their growth targets because of inadequate skills" (Shango, 2019). Furthermore, with the global skills shortage, existing skills become fluid, with the brain drain well documented, especially in sub-Saharan Africa (Mo Ibrahim Foundation, 2018; Ngwé, 2018).

The size of the *informal economy* is a major consideration for trade in Africa. It is estimated that 86% of employment in sub-Saharan Africa is in the informal economy (World Economic Forum, 2019). Although the IMF asserts that the informal sector's share of the global economy has been falling in recent times, it still averages 34% in sub-Saharan Africa, compared to 9% in North America and 15% in OECD countries (Adegoke, 2019). In North Africa, it is an estimated 40% of the average GDP (Abid, 2016). The large size of the informal economy implies that production scales are suboptimal and there are low levels of investment and innovation, and higher tax burdens (Dore, 2015).

Meeting *standards* set by trade partners is often considered to be a barrier to trade with as well as in Africa. Although it is asserted that there are considerable inroads into reducing tariffs and quotas, "to some extent they are being replaced by domestic technical regulations that permit countries to bar products from entering their markets if the products do not meet certain standards" (Mutume, 2006). For example, sanitary and phytosanitary (SPS) measures aim at protecting health of humans, animals and plants, and technical barriers aim at ensuring product quality and safety; however, these can be overshot and used to protect domestic producers from fair competition (Kang & Ramizo, 2017). Murina and Nicita (2014) assert that SPS measures result in relatively higher burdens for lower-income countries and that whilst many middle- and high-income countries have the internal capacity to comply with SPS measures, lower-income countries do not.

Dayan and Petzer (2011) assert that *cultural* elements such as aesthetics, religious beliefs, social organisation, manners and customs and language can create distance between two trading countries. Africa is a vast continent with a diversity of cultures (Good Governance Africa (GGA), 2018). By implication, culture may impact the ability to trade in and with Africa. "Certain specificities of the local cultures in African countries, particularly oral tradition, paternalism, hierarchical distance, collectivism, strong tolerance to uncertainty, and attachment to traditions, may be in opposition to the values embodied in ISO management standards" (Tene et al., 2017). Ferreira and van Eyk (2017) state that cultural elements can further create distance between trading countries by influencing the buying behaviour of customers. Otten (2013) finds that linguistic and genetic distance tend to reduce bilateral trade. Chirwa in White (2021) asserts that a country that may struggle with trade liberalisation is South Africa, pointing to "a local political culture that can be unaccepting of other Africans that come to the country for work". Although these can largely be regarded as impediments to development, GGA asserts that the rich cultural diversity can be used to change attitudes towards work, interpersonal trust, time, youth and women.

The evidence above suggests that there are several factors that need to be taken into account when considering supply chain and logistics in Africa. Although the market is growing, poverty levels impact the ability of local buyers and sellers to enter the market. Logistics infrastructure, although improving in some areas, can be inadequate and add considerably to transport costs and time to market. Border crossing procedures can exacerbate costs and time issues. Political instability can impact the steady flow of goods and corruption can add to logistics costs. Skills shortages imply that it may be difficult to access on-the-ground expertise to work out local logistics arrangements. The large informal sector implies that many logistics arrangements need to be made through less formal channels, implying the need for insider knowledge, whilst cultural barriers may make this more difficult to achieve. The need for compliance with international SPS or technical standards often requires that additional measures be put in place to ensure that products meet the standards required in the purchasing country, whether another African country or other international markets.

3 Logistics Developments in Africa

Notwithstanding the issues outlined above, in considering logistics from an African perspective, it is critical to recognise that Africa consists of individual and diverse countries and logistics challenges and opportunities are not common to all in terms of both incidence and extent. Excedea (2020) states ". . . a common fallacy is to think of Africa as a single, homogeneous entity when in fact the continent consists of 54 distinct countries with versatile histories, as well as economic and political structures". There are vast differences between the least developed market, Niger, and the highest ranked, Mauritius. There are also considerable differences in market size, with Nigeria having overtaken South Africa as largest economy on the continent but performing relatively poorly compared to South Africa and Egypt, Kenya and Tanzania in terms of the Logistics Performance Index developed by the World Bank (see Table 1). Avasthy et al. (2015) add that conditions for businesses vary dramatically with most southern African countries being in the top half of the World Bank's "ease of doing business" ranking, and most countries in central Africa sitting in the bottom quartile. The quality of logistics infrastructure also varies with several airfreight hubs in the south and east of the continent (Nairobi, Kenya; Addis Ababa,

Table 1 Aggregated LPI 2012–2018[a] [Source: World Bank (2019)]

Country	LPI rank	LPI score	Customs rank	Customs score	Infrastructure rank	Infrastructure score	International shipments rank	International shipments score	Logistics competence rank	Logistics competence score	Tracking & tracing rank	Tracking & tracing score	Timeliness rank	Timeliness score
South Africa	29	3.51	29	3.29	28	3.39	26	3.53	33	3.42	30	3.56	31	3.85
Egypt, Arab Rep.	60	2.95	65	2.67	55	2.91	59	2.94	55	2.95	64	2.91	67	3.30
Kenya	63	2.93	67	2.66	67	2.68	70	2.86	60	2.88	53	3.11	61	3.35
Tanzania	67	2.88	69	2.66	63	2.72	66	2.89	65	2.80	69	2.85	62	3.34
Nigeria	103	2.59	145	2.15	88	2.50	118	2.52	100	2.54	83	2.73	86	3.10

[a]"The Aggregated LPI combines the four most recent LPI editions. Scores of the six components across the 2012, 2014, 2016 and 2018 LPI surveys were used to generate a 'big picture' to better indicate countries' logistics performance. This approach reduces random variation from one LPI survey to another and enables the comparison of 167 countries. Each year's scores in each component were given weights: 6.7% for 2012, 13.3% for 2014, 26.7% for 2016, and 53.3% for 2017. In this way, the most recent data carry the highest weight. The Aggregated LPI allows for comparisons across 167 countries" (World Bank 2019)

Ethiopia; and Johannesburg, South Africa), whilst air cargo capacity in West Africa is limited, although there are developments in Angola and Nigeria to develop additional capacity. There are also significant variations in logistics costs and lead times required to access the various African markets (Avasthy et al., 2015).

Table 1 depicts the aggregated LPI scores for some major countries in Africa published by the World Bank over the years 2012–2018. It is notable that there are wide differences in logistics capabilities amongst these major countries. A similar observation applies to most of the other African countries.

Whilst little homogeneity exists between the countries, each with diverse customers and development requirements (Solistica, 2019), there are several emerging developments and trends which are likely to reshape logistics and supply chain practices across the continent in the coming years.

The *African Continental Free Trade Agreement (AfCFTA)* is being seen as the world's largest free trade zone since the establishment of the World Trade Organization (WTO) (Hashi, 2019; Srinivasan, 2019). The agreement aims to create a single market for its member states' goods and services, facilitate free movement of people and investments, promote industrial development and sustainable and inclusive socio-economic growth, and eventually launch a single-currency union (DHL, 2019; The Africa Logistics, 2021). The agreement aims to reduce trade costs and enable integration of African and global supply chains, eliminating 90% of tariffs and also focussing on removing non-tariff barriers (Kende-Robb, 2021). Reducing red tape and simplifying customs procedures should also result in income gains (Kende-Robb, 2021). It is currently estimated that Africa accounts for only 2% of global trade (Kende-Robb, 2021), and intra-African trade only accounts for 16–18% (The Africa Logistics, 2021).

The International Monetary Fund (IMF) estimates that eliminating tariffs could boost trade in the region by 15–25% and double that if other non-tariff barriers are reduced (Srinivasan, 2019). "Those include poor road and rail links, large areas of civil unrest, border bureaucracy, and corruption that have held back growth and integration" (Srinivasan, 2019). For African-owned companies, new markets in the region will become more accessible (DHL, 2019), and large economies such as Nigeria could become crucial entry points for expansion on the continent (Srinivasan, 2019). The agreement should result in bigger markets and therefore upscaled producers and more employment opportunities (The Africa Logistics, 2021); it "opens the door to the creation of more efficient regional supply chains which, in turn, would promote investment, growth, and [again] job creation in Africa" (Diallo in DHL, 2019); the easier process of importing raw materials from other resource-rich African countries will reduce input costs; and it will be easier to set up assembly lines in other countries to access cheaper production (DHL, 2019). The transformative potential of the agreement will however be dependent on the free flow of goods across borders, which logistics must help to unlock (Hashi, 2019). With substandard power systems, airline connections and roads (DHL, 2019), this may impact the ability of less developed countries to take advantage of increased trade, but also presents a major opportunity for logistics service providers to build a network of connectivity in Africa (Kende-Robb, 2021).

The lack of adequate *logistics infrastructure* has been recognised as an impediment to growth and development in Africa (Maier, 2020), and infrastructure deficits and fragmentation of supply chains could be a major constraint to the success of AfCFTA (Kituyi, 2019). Kituyi further asserts that Africa is not investing enough in infrastructure or connectivity, which hampers regional trade. The World Bank found that poor infrastructure investment reduced national economic growth in sub-Saharan Africa by 2 percentage points each year and cut business productivity by as much as 40 per cent (Tuggee in Smith, 2020). The World Bank's Logistics Performance Index for 2018 (World Bank, 2019) indicates scores of 2.76 (out of 5) for infrastructure in the Middle East and North African region and 2.20 for the sub-Saharan African region, indicating low confidence in infrastructure being fit for purpose.

There is however evidence that infrastructure investments are starting to increase in Africa. Tanger Med port in Morocco, for example, has expanded its annual capacity to nine million TEUs and is now one of the top 20 ports worldwide, with a similar capacity to Hamburg port in Germany (Maier, 2020). Inland dry ports are being developed to reduce congestion and storage costs, with an example being recent developments in land-locked Ethiopia to store containers originating from the port of Djibouti (Hancock, 2020). Transhipment hubs are a further emerging trend to "reduce the perceived requirement to create deep ports in all destinations, but rather to have a number of large hub ports and feeders to smaller ports" (Hancock, 2020). Rail projects such as the Kenya Standard Gauge Railway, linking the port of Mombasa with the capital Nairobi (the largest infrastructure investment since independence), and the Lagos-Kano Standard Gauge Railway, linking the port city of Lagos with Kano in Nigeria over a distance of 2700 km (Cairns, 2021), are evidence of the growing need to connect hinterlands with import and export opportunities and grow market connectivity.

Broader connectivity projects are also gaining traction, such as the Dar es Salaam Corridor, which links the Democratic Republic of the Congo (DRC), Malawi and Zambia with the port of Dar es Salaam in Tanzania, and also serves the southern part of Tanzania. The project includes infrastructure and system improvements, rationalisation of rail operations and one-stop border posts, amongst others (Devex, n.d.). Similarly, the North-South Corridor (NSC) is a multimodal transcontinental interconnector including South Africa, Botswana, Mozambique, Zambia, Zimbabwe, Tanzania and Malawi, but ultimately aimed at connecting Cape Town in the south with Cairo in the north (AUDA-NEPAD, n.d.). The programme includes inter-related projects that address "road infrastructure, road transport facilitation, management of railway systems and rail infrastructure; physical and procedural improvements at border crossings; port infrastructure; management of air transport; and energy interconnectors" (The Infrastructure Consortium of Africa, 2012). Growing levels of transport infrastructure investments and increases in connectivity projects, such as smart corridors, indicate a growing desire to provide the infrastructure to enable AfCFTA and have the potential to transform intra-African trade.

Along with infrastructure investments to improve connectivity is the need for *liberalisation of air transport* on the continent. El-Houry (2019) estimates that

Africa makes up 12% of the world's population, but only 2.5% of the world's travellers, 1% of the world's air transport market (Hattem, 2017). The poor levels of air connectivity have a major effect on the ability to trade on the continent, given that air is often the only means of travelling between countries that have limited rail and road connections. Across Africa, flights between destination pairs are infrequent, expensive and often indirect (Hattem, 2017), and African travellers frequently have to travel through European or Middle Eastern hubs to reach another African destination. Hattem (2017) goes on to assert that this is due to a "combination of protectionist legal barriers and regulatory hurdles, mixed with inadequate infrastructure, high taxes, and stubborn nationalism". An InterVISTAS report (2014) states that, whilst there have been considerable strides in liberalising air markets between Africa and other countries, intra-African markets remain largely closed, being governed by restrictive bilateral agreements. This limits growth and development of the air transport market and trade in general and was recognised in the 1980s and 1990s by many African nations, which adopted the Yamoussoukro Decision (YD) in 1999, which aimed at deregulating air services and promoting regional markets opening to transnational competition (InterVISTAS, 2014). The report goes on to state that if just 12 key African countries opened their markets and increased connectivity, an extra 155,000 jobs would be created and annual GDP increased by US$1.3 billion. The potential for growth is evidenced by the South Africa-Zambia bilateral open skies agreement in 2013 which resulted in fares dropping by 40%, or the agreement between Morocco and European airlines, which resulted in lower fares and doubled passenger numbers (Hattem, 2017).

Despite the recognition of the need for liberalisation in the YD, deregulation has made little progress until recently, when the Single African Air Transport Market (SAATM) was created in 2018 to expedite the full implementation of YD and is currently seen as one of 12 flagship projects of the African Union Agenda 2063. To date, 34 countries representing approximately 80% of the existing African aviation market have signed up to SAATM (IATA, n.d.). Its success will however depend on effective implementation, although there are several stumbling blocks such as lack of resolution on "independent dispute oversight function, unified competition rules or consumer rights protections" (Quayle, 2019) and fear of major airlines dominating the market at the expense of smaller players. Air transport is however transforming rapidly in Africa, as evidenced by success stories such as Ethiopian Airways, which has grown, through acquisitions, partnerships and strategic investments (Quayle, 2019), to take advantage of its geographical positioning between African and Asian expansion (UrbanNext, 2019). Although air cargo is still constrained by inadequate infrastructure, such as lack of cold chain facilities (Albakri, 2020), and limited cargo services (Nair, 2020), air cargo in Africa grew by 6.8% in January 2020, compared to the global decrease of 3.3% (African Aerospace, 2020). Although 2020 showed poor cargo performance globally, figures indicate recovery beyond pre-crisis levels, citing a 22.4% increase in January 2021, compared to January 2019 (Finlay, 2021). Coupled with developments such as drone deliveries (Nair, 2020), development of air cargo facilities such as the proposed construction of the midfield air cargo terminal at O. R. Tambo, Johannesburg (Shilowa in Campbell 2019), and surges in e-commerce on the continent (Campbell, 2019), air cargo is set for major growth in Africa in the near future.

Africa's economy has traditionally been dependent on *extractive and agricultural sectors*. More than half of Africa's people are dependent on agriculture for part or all of their livelihoods (NEPAD, 2013), and commodities account for more than 80% of exports in 35 of the continent's countries (Bloxham, 2019). In sub-Saharan Africa, it is estimated that 89% of countries are dependent on commodities, compared to two thirds of the Middle Eastern and North African countries (UNCTAD, 2019). Whilst much of the economic growth on the continent has been linked to the post-millennium commodity super-cycle (Bloxham, 2019) and much of the opportunities in Africa are related to its abundant resources, their importance should not be overestimated. A Goldman Sachs report indicates that only 30% of Africa's GDP growth since 2000 can be linked to commodities (Coleman, 2020), and Africa's role in commodity markets is relatively small, with its exports of major commodities comprising less than 10% of global trade flows (Bloxham, 2019). This heavy dependence on commodities, and the associated risk of resource price fluctuations, thus suggests that Africa needs to broaden its economic base (IMF, 2011). Some of the opportunities for this is in agriculture. Africa possesses 60% of the world's uncultivated arable land (Coleman, 2020), but only 23% of sub-Saharan Africa's GDP is derived from agricultural activities (Goedde et al., 2019), suggesting massive potential for expansion. Goedde et al. (2019) further asserted that Africa could produce two to three times more cereals and grains, adding 20% to the current worldwide output, and similar increases could be seen in horticulture crops and livestock. Technology solutions are also driving growth in these areas, such as Twiga Foods in Kenya, which connects produce from rural areas to urban consumers on an easy access platform, and InspiraFarms, which provides off-grid solar solutions to enable cold storage solutions in rural areas, thus increasing opportunities for farmers (Hashi, 2019).

Leke and Signé (2019) also assert that Africa is *industrialising*, producing goods ranging from processed foods to automobiles, and has the potential to double production within a decade. de Vries et al. (2021) suggest that the de-industrialisation trend in Africa pre-2000 is reversing and manufacturing is increasing; however, this has not resulted in increased manufacturing productivity, likely because manufacturing growth is being driven by smaller firms. Whilst much of this manufacturing appears to be aimed at satisfying local demand (de Vries et al., 2021), Simons (2019) suggests "a subtle trend of Alibaba industrialisation, wherein small and medium-sized Chinese suppliers provide major chunks of the industrial jigsaw and African hustlers and unconventional industrialists act as shuttle-brokers of the various factors of production between China and Africa". Other industrial opportunities are backward and forward linkages within the extractive sector (Ramdoo, 2013; Langa & Nkhonjera, 2018). The potential growth in the agricultural sector, small-scale growth in manufacturing to meet local and intra-African demand as well as grow exports, and linking extractive and other sectors all suggest changing patterns of demand. Coupled with the increased demand associated with a growing market, the implication is a major shift in movement requirements across the continent. Growth sectors in Africa will drive demand for transport and logistics, and PwC (Temkin, n.d.) suggests that logistics strategists cannot afford to ignore the African market of the future.

Wolfenden (2020) claims that Africa's economy is entering a phase of "supercharged mobility", enabling it to bypass the traditional model of linear growth through a combination of *technology*, globalisation and demographics. Diop (2017) states that technology and innovation is transforming Africa, with phones enabling banking for millions of previously unbanked people, farmers can access crop prices and buyers, patients can get hearts examined, solar panels can be ordered online and blood can be delivered by drones. Gilbert (2020) and Wolfenden (2020) both assert that there are nearly half a billion mobile phone subscribers in sub-Saharan Africa alone, although this still only represents approximately a 45% penetration rate, suggesting enormous scope for growth. Internet usage is still low, approximately 26% in sub-Saharan Africa, but is growing at a rapid rate, as smartphones' adoption comprised 50% of connections in 2020 (Gilbert, 2020). Maier (2020) avers that Africa, the youngest continent, with 60% of the population under 25 years of age, has a digitally minded population demanding smart, digital solutions. He goes on to say that this makes Africans more open to change and able to adopt new technology much faster. M-Pesa, a payment platform, has allowed for instant transfer of financial resources between people and entities, and the ability to connect virtually has meant a jump in intra-African trade from 10% a decade ago (Wolfenden, 2020) to approximately 17% today (The Africa Logistics, 2021). Twiga Foods and InspiraFarms, mentioned above, are examples of the development of services for rural communities (Hashi, 2019). Whilst logistics is not being reinvented in Africa—goods are still transported by motorbike, bicycle, cars, trucks, rail and boats—innovation is allowing for the matching of supply and demand on digital platforms (Hashi, 2019). mPharma, from its base in Ghana, is now sourcing and circulating reliable medicines across Africa (World News Daily, 2020). Kobo360 in Nigeria, for example, connects truckers and companies to delivery services, has expanded its services to four different countries since its launch in 2017, has more than 10,000 drivers and trucks on its app and provides services to big organisations like DHL and Unilever (Hruby & Rugo, 2020). Similar services are springing up across the continent. Musanga in Zambia works with FMCG brands to deliver products countrywide; Acquantuo in Ghana allows people to transport goods from country to country using spare space in their bag or vehicle; Parcel-it in Nigeria targets local deliveries in Lagos, using motorbike deliveries; Pargo in South Africa offers click-and-collect and return solutions for online and omni-channel businesses, allowing customers to use dedicated pickup points; and Senga is an on-demand trucking platform connecting users and suppliers in East Africa (Nieuwoudt, 2019). The access to top-quality education, previously only accessible to the developed world (Wolfenden, 2020), should also be seen as another benefit of digitisation to logistics development in Africa.

Tech start-ups, providing access to wider markets, mobility, connectivity, skills and lower costs, as well as improving productivity and speeding up transactions, amongst others, are recognised as the future of logistics in Africa. Botha (2019) asserts that Africa is leapfrogging with innovation and is often quicker to take up technologies such as mobile money, as the majority of Africans are "unbanked" and therefore have no need to hold on to traditional ways of doing business. This is supported by *World News Daily* (2020), where it is stated that one of the reasons for fast development is the fact that there are no legacy tech-enabled players in logistics, farming, medicine and b2b funding. "Nearly half of Africa's economic growth over the next 10–20 years will be driven by a group of still relatively unknown tech companies" (FT Alphaville in Milken Institute, 2020). Despite limited access to finance, tech start-ups raised US$129 million in 2016 (Diop, 2017). The support of groups such as Goldman Sachs for fundraising for Kobo360 (Hashi, 2019) and Toyota's trade and investment arm in Sendy, the Kenyan logistics company, suggest a recognition of the importance of tech companies in Africa's future logistics growth. Excedea (2020) follows that the continent is already home to 618 technology hubs and "[c]ompanies ought to consider these innovation ecosystems as one potential entry point for African markets".

Moving goods across the continent remains challenging with an often poor road network, long lead times and costs, inadequate addressing systems and lack of signage, lack of supply chain visibility, 3PLs that avoid smaller centres and rural areas, less than truckloads, and supply chain risks such as protest action and conflicts (Nieuwoudt, 2019). These are however being addressed in innovative ways. Besew in Ethiopia is mainly a peer-to-peer courier service aimed at traditional transport collaboration and allows individuals that are planning trips to a selected location to share transport costs and reduce less-than-truckloads (Nieuwoudt, 2019). In recognising that many big websites don't ship to Africa, but African consumers are looking for products from Europe and the USA, Quicarry delivers packages from international e-commerce websites in Senegal (Russon, 2019), as does DHL Africa eShop (International Finance, 2019). The poor addressing system in many countries is overcome by ventures such as Kenyan start-up OkHi, which provides the user's mapped coordinates and a picture of the front of their house to an approved delivery person (Bhattacharya, 2019); Aquantuo applies GPS, instant messaging, online and mobile payments, mobile technology and SMS notifications to logistics, so that any item anywhere in the world can be purchased and delivered to the doorsteps of its clients in Ghana; and Pargo, in South Africa, solves the last mile challenge by using Pargo points, located at convenient retail stores, for parcel delivery and collection (International Finance, 2019). Remote locations are accessed via big-wheel vehicles to overcome rough roads or drone solutions (Kannoth, 2019) such as Zipline, which delivers blood and medical supplies in Rwanda (Botha, 2019), and DHL in Tanzania (International Finance, 2019). Smaller tech companies such as Copia deliver crucial products for outlying locations and have rural distribution points (World News Daily, 2020), and Sokowatch, in Nairobi, focuses on supply chains for the informal sector (Hashi, 2019). Blockchain technologies are used by companies such as TMX Global in Kenya to provide a decentralised system that includes supply chain stakeholders and allows them to communicate with each other to reduce costs and increase efficiencies by integrating shipment information on a secure platform (International Finance, 2019).

4 Future Logistics Skills Requirements

Developments in supply chain and logistics in Africa tend to be centred around circumventing current challenges. Intra-African trade, for example, is constrained by lack of cross-continental connectivity as most road and rail networks flow from the inland areas to the ports with little cross-continental connectivity. This is still a legacy of the influence of the colonial era which focused on mineral exports to First World countries from Africa. AfCFTA and SAATM both recognise the constraints and aim at improving connectivity in Africa. This suggests the need for high levels of cooperation at all levels, from strategic government negotiations to project management to cross-border operational issues. Some of the issues in operationalising regional-level cooperation agreements relate to availability, quality and harmonisation of infrastructure as well as cross-border arrangements, again suggesting cooperation and collaboration at various government and private sector levels.

On the other hand, the development of the extractive and mining sectors and beneficiation at source, the high degree of industrialisation and the leapfrogging of technologies suggest a broader range of technical skills required for logistics across the continent. Historically, industrialisation has resulted in replacing existing skills sets with new ones—mechanisation resulted in fewer jobs performed by hand and reskilling to boilermakers, ironmongers, mechanics, etc. The later expansion of steel, oil and electricity required further technical skills development. Similarly, computerisation required new jobs such as hardware and software developers. The Fourth Industrial Revolution will require comparable reskilling. Thus, each revolution, where job losses were feared, resulted in the development of new technical skills (de Pliejy et al., 2018; Noble, 2020). Africa, characterised by various stages of development, and simultaneously experiencing industrialisation, growth in mining and agricultural mass production and the Fourth Industrial Revolution, is likely to require a very broad range of skills ranging from engineers, farmers and miners to data analysts, innovation specialists, big data practitioners and digital transformation specialists. Gachanja (2020) recognises amongst the top ten sought-after jobs in Africa as those in agriculture, infrastructure, mining, service sector, banking and finance, ICT, entrepreneurship and transport and logistics (with the remainder being entertainment and tourism), thus indicating an enormous need for skills across a wide range of sectors. In South Africa, this is confirmed by the Department of Higher Education and Training (2020) and Kwatch (2021), highlighting critical skills shortages in ICT, engineering, business, management and economics and quality and regulatory professionals, amongst others.

The need for hard technical skills is thus evident and will require considerable interventions in future years to meet the requirements for the changing supply chain landscape. In particular, note is taken of the need to change skills sets to accommodate the technological developments across the continent. Ra et al. (2019) assert that “[n]ew jobs are more likely to be concentrated in the nonroutine and cognitive category requiring higher-order cognitive and soft skills”.

Several authors have previously considered the skills required for logistics and supply chains. Murphy and Poist's (2006) seminal work proposed the BLM framework, asserting that logistics managers required business skills, logistics skills and management skills, the latter of which they asserted were the softer skills required to perform the logistics function. These included aspects such as persuasion and negotiation, analytical skills and ability to adapt to change, amongst others. These soft skills are also recognised by the Association for Supply Chain Management (ASCM, formerly APICS), in their Supply Chain Manager Competency Model, where foundational skills include academic competencies, but also personal effectiveness competencies such as the ability to communicate, and workplace and leadership competencies such as collaboration, conflict management and enabling technology (APICS, 2014). Work done in Africa (Luke & Heyns, 2019) recognised logistics analytical (technical) skills as critical, but also concluded that logistics awareness ("big picture" skills), general management and behavioural/interpersonal skills were just as important to doing business. Mageto and Luke (2020) proposed a framework consisting of logistics skills, business skills (including IT-related skills and relationship management), management skills (including cross functional coordination and change management) and ethics and environmental skills, again highlighting the need for technical/hard skills, but placing a major emphasis on the need for softer skills in logistics and supply chain management.

Softer skills touted as critical in the Fourth Industrial Revolution include creativity, emotional intelligence, analytical thinking, active learning, decision-making, leadership skills, diversity and cultural intelligence, technology skills, embracing change (Marr, 2019), complex problem-solving, critical thinking, people management, coordinating with others, service orientation, negotiation and cognitive flexibility (WE Forum, 2016). Deloitte (2018) highlights these as communication, critical thinking, creative thinking, collaboration, adaptability, initiative, leadership, social emotional learning, teamwork, self-confidence, empathy, growth mindset and cultural awareness.

Crucial developments in logistics in Africa require expansion of infrastructure to achieve intra-African connectivity; cooperation at regional levels to ensure the success of cooperation arrangements such as SAATM and AfCFTA; growth in extractive, agricultural and industrial exports; and extensive technological advances. Africa is in need of a wide range of technical skills; however, to enable such growth and connectivity within the Fourth Industrial Revolution, there needs to be recognition of the diversity on the continent, and the most critical skills will thus be the ability to think analytically, cross cultural barriers, communicate, collaborate, negotiate and manage change.

5 Conclusion

Logistics performance is an important enabler to trade (Tang & Abosedra, 2019), yet for years Africa's trade has been hampered by the low levels of mobility of people and goods, poor infrastructure, low demand, a massive informal market, corruption and political instability and a chronic shortage of skills. Logistics performance, which is measured by the World Bank (2019) as comprising of customs performance, infrastructure, international shipments, logistics competence, tracking and tracing and timeliness, has been consistently low in most sub-Saharan and North African countries. Muogboh and Ojadi (2018) suggest that, in order to improve logistics in Africa, it is necessary to promote a high-quality service and reliability over cost, build partnerships, engage the local citizens and seek to be a citizen, take advantage of emerging trade corridors, provide logistics infrastructure, reduce security risks and use technology and thinking out of the box to overcome environmental constraints. With a growing young population and shifting sectoral growth from commodities and agriculture to expanded agriculture solutions, industrialisation, service industry growth and tech adoption, it is suggested that patterns of trade in and with Africa are changing at a rapid rate. Although billions are still required to achieve the connectivity required across the continent, infrastructure investment is on the increase.

Africa's free trade area, envisaged by AfCFTA, suggests that long-term sustainable partnerships are being recognised as solutions to the low levels of intra-African trade, as well as provide the impetus to taking advantage of emerging trade corridors. Ongoing regulatory reforms (Maier, 2020) suggest facilitation of customs procedures and more engaged citizenry, both of which ease the flow of goods across the continent. Technology start-ups and solutions go a long way to addressing a multitude of existing logistics issues including timeliness, reliability of service, tracking and tracing, reducing security risks and even increasing competence. Kanza (2020) further emphasises that Africa must embrace digital technology to build resilience for the post-COVID-19 world. The recognition of these developments by multinational logistics and financing companies indeed suggests that Africa is rising. Lawson (2020) asserts that this needs to be taken further by not returning to business as usual by relying on foreign interventions but build local solutions to harness Africa's uniqueness. Developments in logistics across the continent seem to indicate that local solutions are deactivating past challenges, promoting Africa's resilience and aiding a strong recovery (Signé & Dollar, 2020) whilst ensuring that it becomes a stable and prosperous economic partner for the rest of the world (Coleman, 2020) to secure a more robust economic future.

Management Perspective on Challenges and Opportunities for Logistics in Africa in the 2020s

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A Logistics Practitioner's Perspective

Africa's strategic importance within the global supply chain, coupled with the increased interest in its markets, has placed Africa squarely in the spotlight of its major global trading partners.

Global trade is dependent on efficient supply chains, regional corridors and ports to be competitive in the international markets. Africa's regional corridors, linking the ports to the hinterland, are operating at different level of efficiency, but it is true to say that a number of corridors are in a process of major evolutionary change. Africa's trading partners require a steady supply of commodities for their production processes and in turn to place their manufactured products into the various regional African markets.

The regional African markets in mining, manufacturing and supply chains all contain pockets of excellence in their skill sets. It is however a definite requirement for further skills transfer along the entire value chain to ensure that Africa becomes a world-class player in the global markets. The transfer of hard and soft skills needs to be transferred by multinational, non-governmental organisations and institutions of higher learning. Universities need to play a more dynamic role on a regional and international front. They need to undertake research and be actively involved in the transfer of required skill sets as to compliment the substantial logistics infrastructure developments that are currently taking place across the continent.

The logistics landscape of Africa is also set to change in the next decade as the North-South Corridor, which carries 60% of the region's trade, is challenged by the new East-West Corridor between the Port of Lobito in Angola and the new 20-million TEU mega-port in Bagamoyo in Tanzania. Once the two ports are linked by the new rail link via the DRC and Zambia's mining regions, cargo will start to flow East-West. The projects are mainly funded by China as part of their maritime Silk Road project and their broader Belt and Road initiatives.

Infrastructure developments in Kenya, also funded by the Chinese, include the Standard Gauge Rail project, linking the Port of Mombasa to Nairobi. Future anticipated extension to Uganda, Rwanda and South Sudan is set to open the mineral-rich Great Lakes Basin. The new mega-port of Lamu in northern Kenya is set to create a new corridor to Sudan and Ethiopia, thus challenging the current Djibouti-Addis Ababa Corridor.

(continued)

The Port of Alexandria in Egypt recently replaced the Port of Durban in South Africa as the largest container port in Africa, but in turn will be replaced by the Port Tangier Med in Morocco as it expands by a further six million TEUs. Morocco is linked by the Maghreb highway, via Tunisia to Egypt to form a corridor on the Mediterranean coast.

In West Africa, the four corridors of Abidjan-Ouagadougou, Accra-Quaga, Lomé-Quaga and Abidjan-Lagos connect four countries making up the West Africa Growth Ring.

In addition to ports in Tanzania, Kenya, Djibouti and Angola, China through its China Merchants Holding became a key investor in the West African Ports Lomé, Togo and Lagos.

Recently, reports in the *The Wall Street Journal* revealed that Africa's debt owed to China has piled up to a whopping $143 billion over the past two decades.

Although China and Chinese companies remain the dominant investors in Africa's infrastructure, and especially in ports, African leaders are becoming more demanding that Chinese-funded projects align with African development needs or at least with Africa's political interest. This dispute also raises questions over Chinese business practices and what US officials characterise as China's "debt trap diplomacy".

China's Maritime Silk Road ambitions suffered a setback after Tanzanian official refused to budge over stalled negotiations to build the Port of Bagamoyo what would be the largest deepwater port in Africa and has suspended the project indefinitely. They are currently showing no signs of backing off in follow-up negotiations. Instead, Tanzanian officials offered the Chinese company a blunt ultimation: accept our conditions or leave.

Whether more African leaders will adopt such an approach is uncertain, but similar examples, such as the government of Sierra Leone cancelling the construction of a new airport in 2018, suggest that Chinese investors may face more scrutiny over current and future development project in Africa.

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