Contributions to Management Science

Meng Lu
Joost De Bock *Editors*

# Sustainable Logistics and Supply Chains

## Innovations and Integral Approaches

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Editors

# Sustainable Logistics and Supply Chains

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# Foreword

Although logistics has undergone huge improvement over the past few decades, there is general agreement that much more can still be done to improve its efficiency. This can be illustrated by a few statistics. 45 % of Europe's freight moves by road in trucks that, in weight terms, achieve an average load factor of only 43 %. This is partly because they run empty on a quarter of the kilometres they travel, but also because on the laden kilometres they use only 57 % of their available load carrying capacity. The empty running is often blamed on imbalances in traffic flows, but analysis reveals that this only accounts for around half of the empty kilometres. The potential probably exists to increase the average truck load factor in Europe enough to cut road haulage costs by over 20 billion €. If a wider range of improvement measures could trim around 10 % from the total annual EU expenditure on logistics of 930 billion €, savings in the order of 100 billion € could be released. This is a similar figure to the annual cost of traffic congestion and pollution to the EU economy, much of which is due to the movement of freight and likely to be reduced by efficiency gains across the logistics sector.

Achieving deep cuts in the economic and environmental costs of European logistics will require more than the efforts of individual companies working in isolation. It will need to be reinforced by the collective action of groups of companies working together to share assets and services. If they do this, they will be able to harvest much of the so-called 'low hanging fruit', which yields both economic and environmental benefits. This, however, will require major changes in business practice and managerial mindsets. In today's intensely competitive markets, self-preservation tends to be the initial reaction rather than a greater willingness to co-operate across the supply chain.

Research can play a key role in promoting greater supply chain collaboration: research on ICT but more importantly on the new collaborative business models required to exploit opportunities for efficiency improvements and value creation. The development and application of these models are lagging behind advances in ICT.

The main constraints on freight transport efficiency are usually organisational and extend beyond the conventionally defined boundaries of logistics into production strategies and the behaviour of distributors and consumers. In serving the needs of the production process and the demands of customers, logistics managers have often to accept a significant loss of transport efficiency. This inefficiency can be seen in purely budgetary terms, making transport more expensive in the pursuit of lower production costs and higher sales. This, however, underestimates the wider environmental and societal costs associated with transport inefficiencies. All too aware of these inefficiencies, logistics managers have a responsibility to try to persuade their manufacturing colleagues to be more ‘lean and green’ in their design of production processes and setting of productivity targets.

In the long term, the answer may lie in a completely different type of logistical system modelled on the principles underpinning the Internet. This concept of a ‘Physical Internet’ has attracted a great deal of attention over the past few years, with some viewing it as science fiction and others seeing it as a credible vision of how logistics may evolve over the next few decades. Some past innovations that proved transformational for logistics, such as containerisation and e-commerce, also met with initial scepticism. Making the Physical Internet a reality will be a huge challenge and requires levels of industrial co-operation, asset sharing and supply chain transparency well above those prevailing today, but research is already underway to explore how this might be achieved.

This book is an important contribution to the development of European research on the restructuring to logistics systems and supply chains to deliver substantial increases in efficiency and value. In studying the spectrum from the short-term exploitation of new collaborative opportunities to long-term recasting of logistics as a Physical Internet, researchers must work closely with managers in logistics and related functions to keep their work practical, realistic and relevant. The new European Technology Platform for Logistics (ALICE) exists to promote such industry–researcher interaction and help to ‘future-proof’ the proposed solutions which emerge from the work. As one of ALICE’s first outputs, this book demonstrates the very valuable contribution it can make.

Edinburgh
March 2015

Alan McKinnon

# Preface

Besides being indispensable and bringing substantial economic benefits, logistics is undoubtedly also associated with considerable negative impacts on society and the environment from the related transport operations and infrastructure needs. But at the same time, innovation and deployment of new concepts in logistics can be an instrument for greening the society. Efficiently accommodating reverse-flows logistics is just one obvious example of this.

An overarching concept for an advanced, innovative and integrating approach for logistic and supply chain is a key component of a future transport system that is intelligent and sustainable. It will provide a significant contribution to making the transport system more efficient, cost-effective, safe, reliable, competitive and environmentally friendly, in a way that other sectors and the European economy as a whole will benefit.

Advanced and innovative solutions for improving logistics performance and increasing its sustainability have recently attracted increasing attention from industry partners, academia and politics for this nontraditional sector. This book addresses main challenges in the area of logistics and supply chain management, and key findings based on solid research, as well as on elaboration of specific business cases.

This book was produced with the kind help and support of the WINN Consortium (European Platform Driving knoWledge to INNovations in Freight Logistics), ALICE (Alliance for Logistics Innovation through Collaboration in Europe), the European Commission and other research institutes and universities. We would like to express our sincere gratitude to our colleagues and friends who contributed directly or indirectly to this book, and in particular to Dr. Arjan van Binsbergen (Technical University Delft), Dr. Remco Overwater (DINALOG, Dutch Institute

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**Valentina Boschian** received her Ph.D. at the University of Trieste in information technology engineering in 2012 and focused on the study of multi-actor systems and of the impact of advanced ICT on intermodal logistic system. She is also involved since 2008 in various EU-funded projects (including EURIDICE). She has publications in congress proceedings and scientific journals especially on topics related to supply chain and intermodality. Valentina has skills in business models analysis and modelling performance assessment.

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**Uwe Clausen** is Managing Director of the Institute of Transport Logistics at TU Dortmund University and director of the Fraunhofer-Institute for Material Flow and Logistics in Dortmund (since 2001). He worked in the logistics service industry as European Operations Director at Amazon.com and logistics manager at Deutsche Post DHL. In July 1995, he achieved the title of Dr.-Ing. with his doctoral thesis on transportation network optimisation at TU Dortmund University. He is Member of the board of ECTRI European Conference of Transport Research Institutes, the Advisory Council of the Association of German Transportation companies (VDV) and the scientific advisory board of the Bundesvereinigung Logistik (BVL) e.V. His research areas include green logistics, commercial traffic modelling, intermodal transportation, mathematical optimisation, network optimisation and distribution systems.

**Joost De Bock** worked for the European Commission (EC) since 1992 with mission to support development of an autonomous transport research programme in the context of European Framework Programme. He serves as Scientific or Project Officer of the EC responsible for the adequate execution of EU (European Union) co-funded research projects, addressing different modes (road, rail, waterborne and intermodal), as well as other issues such as safety, production process, logistics and carbon footprint. Previously, he worked at the Dutch Ministry of Transport, The Netherlands.

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**Alan McKinnon** is the Head of Logistics in the Kühne Logistics University, Hamburg. He has been researching and teaching in freight transport and logistics for 30 years and has published extensively in journals and books. He is a frequent contributor to academic and business conferences on logistics around the world. Alan has undertaken research and consultancy studies for numerous public and private sector organisations in the UK and overseas and been an adviser to several UK government departments, the European Commission, the OECD/International Transport Forum and the International Energy Agency. Between 2010 and 2012, Prof. McKinnon was Chairman of the World Economic Forum's Logistics and Supply Chain Industry Council and in 2014 elected chairman of the Transport Advisory Group of the EU Horizon 2020 programme.

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# Logistics Trends, Challenges, and Needs for Further Research and Innovation

**Uwe Clausen, Joost De Bock, and Meng Lu**

**Abstract** Logistics and transport are central elements and pre-conditions of worldwide trade and business. Sustainable transport solutions are vital for societal acceptance: economic growth with less resources and even less environmental impact will be crucial for European countries and globally—access to markets at reasonable transport prices is a cornerstone for the benefits of globalisation. Sustainability in logistics includes ecological, economical and social objectives. Challenges arise from a global, competitive environment, restrictions, social or ecological concerns, as well as deficits in information flows, knowledge transfer or well integrated ICT applications. This chapter provides an overview of the trends and challenges in the area of logistics and supply chain management and addresses the needs for research and innovations. In addition, it describes the structure and the main themes of the other chapters of this book.

## 1 Introduction

Logistics, and especially better solutions for sustainable logistics, have attracted increased attention from industry partners and academia in this non-traditional sector, as well as from decision makers. The term logistics used here refers to traditional logistics and the whole supply chain management (see Figure below), and is therefore not limited to its narrow interpretation of just freight transport.

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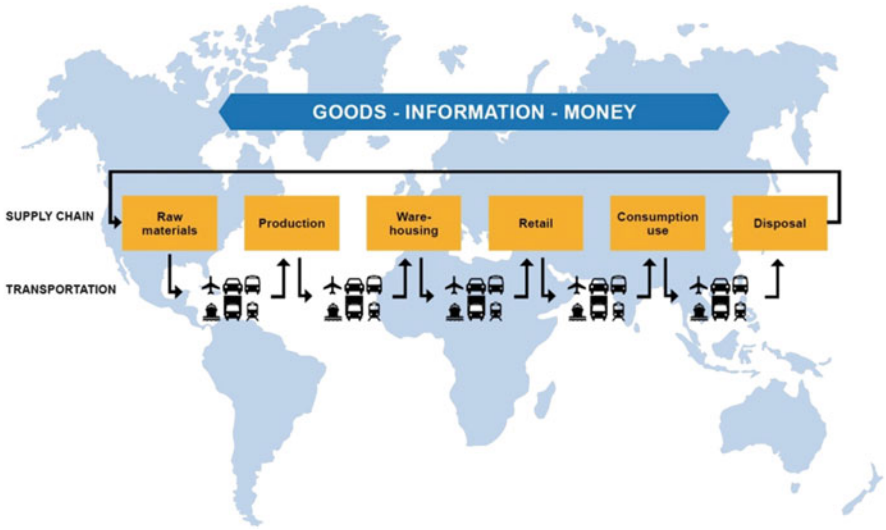


(Source: DINALOG)

An overarching advanced logistics and supply chain concept, may significantly contribute to a more sustainable intelligent transport system, by making it more efficient, cost-effective, safe, reliable and competitive, in such a way that other sectors and the European economy as a whole will benefit from this.

The key idea behind the logistics and supply chain planning and control concept is the recognition that decisions on a supply chain level may have effects on transportation that reach far beyond decisions made merely from the transport perspective. At the same time, these effects can only be reached if shippers and logistics service providers join efforts. The decision to redesign the supply chain is typically a manufacturer/shipper decision, and not a decision taken just by the transport sector itself (WINN Consortium 2012).

From social (people), environmental (planet) and economic (profit) perspectives, sustainable logistics and supply chains are the engine for a more competitive and unified European market, and a prerequisite for the further growth in international trade. To be able to comply with these demands, logistics must be highly efficient, reliable, safe, secure, environmentally friendly and cost-effective. For this, the following aspects are of importance: (1) better utilisation of existing infrastructures (nodes/hubs and links/corridors), also from an intermodal perspective; (2) in a highly developed society like Europe, increases in infrastructure capacity cannot always be (cost-effectively) facilitated by physical infrastructure expansion; (3) anticipated shortages in manpower required for physically demanding tasks (driving trucks at night, work in dispatching and distribution centres, and work in intermodal transfer hubs).

Besides its vast positive economic effects, logistics—and especially the related transport operations and infrastructure needs—also puts burdens on society and the environment. An important element of advanced logistics concepts therefore concerns adequate measures to minimise its negative effects, for instance: (1) reduction of the environmental impacts, including the carbon footprint, noise, un-safety and inadequate land use; (2) reduction of the demand for non-renewable resources, including fossil fuels; (3) improvement of external safety and labour conditions.

At the same time, logistics can be an instrument for "greening" the society, for example by: (1) efficiently accommodating "reverse flows" to enable the re-use of components or parts and other "waste" materials, as well as flows of returned products (note that most countries now have regulations stating that a non-satisfactory product may be returned within a limited time period, as happens quite often in the case of internet sales); (2) accommodating the use of alternatives for (traditional) fossil fuels that require mass movement of goods, such as biomass (WINN Consortium 2012).

Confronted with these challenges in the logistics system, we conclude that there is a need for integral—which is not necessarily the same as integrated—approaches that (1) recognise the need for a variety of supply chain, logistics and transport options; (2) embrace and incorporate the potential of (new) technological developments—both those directly related to the transport sector and those developed originally for or in other sectors; (3) take into account technological and infrastructure aspects, as well as aspects related to the organisational structure, information flows, the financial and juridical domain, standardisation/harmonisation and the complexity of implementation—including financial, educational and training issues; (4) coordinate sound business and governance models.

## 2 Globalisation and Logistics

When in 1967 sea ships brought container to Europe for the first time, these vessels only accommodated around 1000 twenty-feet-equivalent units (TEU) and the world's population was estimated to be 3½ billion people. Until today its population has doubled and the capacity of large containerships has even more increased—to more than 18,000 TEU. The volume of containers shipped around the world is just one of many visible signs of the division of labour that has helped to overcome poverty in many parts of the world and led to a tremendous growth of freight transport, regional and cross-border, between continents, especially to and from the Asia-Pacific region.

Globalisation in combination with economic growth is the main reason for global trade. Sea container volume has doubled each of the last three decades and is likely to reach an estimated 1100 Mio. TEU in 2020 (Fig. 1).

Although expected growth is subject to regional differences or even global setbacks coming from political or financial crisis from time to time, the trend does not seem to have come to an end. Most of freight transport activities are still within national boundaries but most of its growth comes from globalisation and ongoing division of labour.

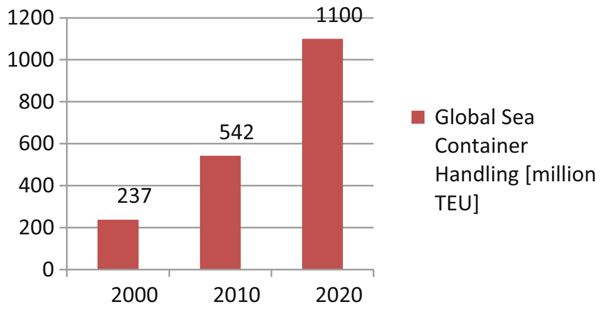


**Fig. 1** Global sea container handling (Drewry 2011)

## 3 Demography and Logistics

For the first time in human history more than half of the population lives in urban agglomerations. Urbanisation in Europe has started earlier with industrialisation in the nineteenth century and has led to more than 70 % of people living in cities. In Asia the share is approaching 50 %. With strong economic growth and more than 60 % of the world's population living in Asia the twenty-first century can certainly be expected to become the "Asian century".

As world's population has been growing beyond seven billion people—doubling the number in not much longer than 40 years—we are not only getting more, but also getting older. What we all appreciate as individuals comes with challenges for society and the corporate world. An ageing society may cause different schemes of risk behaviour, of mobility and certainly consumer behaviour. Innovative combinations of home care and home delivery services may open up new opportunities for logistic services and the healthcare sector.

In the corporate world as well as in public institutions knowledge management concepts need to adjust to demographic changes. With regard to logistics the need to organize warehouses and transport operations as well as other workplace environments to function with higher percentages of elderly employees will require more attention in the sector, especially in Europe. The organisation of transport, information and communication related to the flow of freight will need to reflect this change as well (Fig. 2).

## 4 Energy and Logistics

Looking at global energy consumption from a broader perspective we can state a growing importance of transport and mobility. Whereas 40 years ago, industry had higher portion than transport today both are almost at the same level, consuming 2500 Mtoe each year (Fig. 3).

The world's fear—in the past decades—to run out of fossil fuels has driven innovation in drilling technology and large investments. In between the United

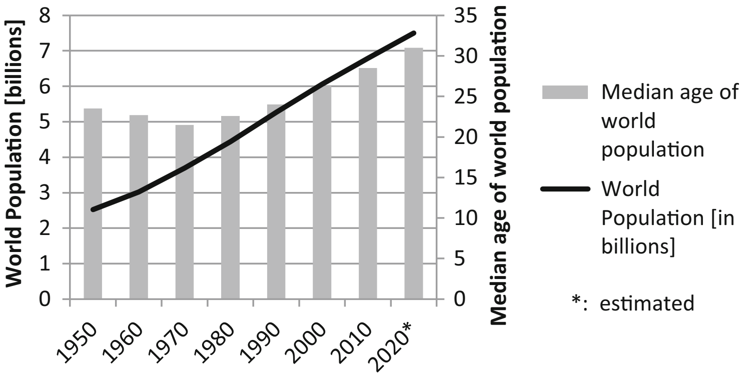


**Fig. 2** World Population and median world population age (United Nations 2013)

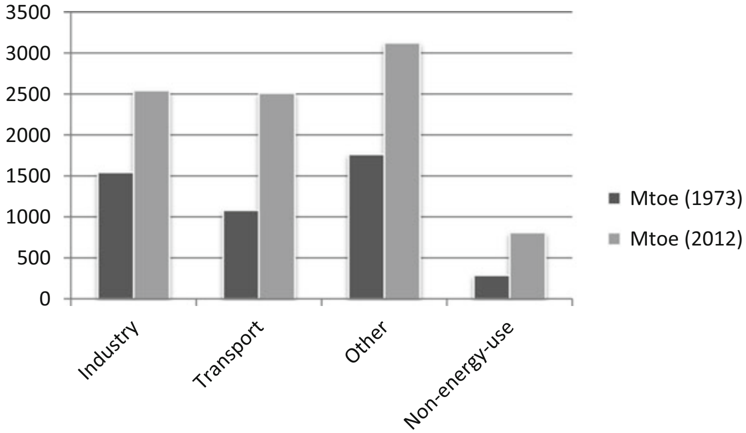


**Fig. 3** World Energy Consumption 1973 and 2012 (International Energy Agency 2014)

States of America have become an oil exporting country and few people are talking about a “peak oil” situation. Not the capacity of fossil fuels in the earth’s noun but the global ecosystem’s capacity to absorb $CO_2$ emissions from the atmosphere does become the major issue and restriction.

The number of the extreme weather events, as for example drought periods, storm, earthquakes and floods has risen globally during the last 30–40 years. On the basis of the results of climate modelling, with various models and the IPCC scenarios, leading research institutes assume a global warming of 1.4–5.8 °C until the end of the twenty-first century. As main reason an increasing concentration of greenhouse gases in the atmosphere during the last 150 years, in particular that of carbon dioxide ($CO_2$), has been identified. Since $CO_2$ is the most significant greenhouse gas quantitatively, its concentration in the atmosphere is used as an indicator for the anthropogenic greenhouse effect. Besides $CO_2$, methane ($CH_4$), nitrous oxide ($N_2O$), fluorinated hydrocarbons as well as sulfur hexafluoride ($SF_6$)

belong to the relevant greenhouse gases. As these gases differ with regard to their effect on the climate, they are weighted and converted into "$CO_2$ equivalents".

The concentration of greenhouse gases in the atmosphere has risen by about 35 % since 1750 and has meanwhile reached a value of about 400 ppm (Meteo World 2014) (parts per million or millionth part in the atmosphere) $CO_2$ equivalents, which increases yearly around 2 ppm. Following the IPCC report from 2014 more the ¾ of the additional greenhouse gas emissions between 1970 and 2010 caused by mankind are from industrial processes and combustion engines. Thus climate change is likely to be in progress and urgency of measures will increase the more it is visible to mankind in the years to come.

Every mode of transport has basic characteristics and strengths. None of it is completely indispensable. With regard to environmental aspects it seems that rather than a new technology serving as kind of a "silver bullet" is vital on all levels, with all modes and from design to operations to incorporate sustainability goals and strategies. Energy-efficient freight logistics processes start with management systems, staff training and the creation of incentive systems, continue with information flow to organize bundling of transport volumes, identification of really necessary service and speed requirements, application of alternative powertrains and fuels and include every day's efficiency efforts of drivers and dispatchers in all systems.

In order to divert attention to the right priorities, the first aim should be to measure accurately (Fig. 4). The best ecological effects are shown when one can completely avoid an activity followed by reduction through efficiency gains. Only as a last step compensation of GHG emissions by offset projects comes into perspective.

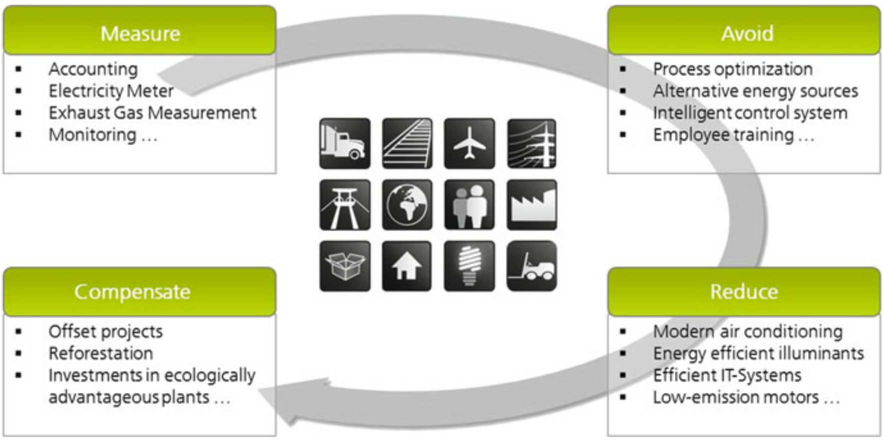


**Fig. 4** Measures to reduce GHG emission (Clausen and Hesse 2012)

## 5 Information Technology, the Internet and Logistics

Since the early days of the semiconductor industry processing power for computers has doubled every 2 years. Moore's Law in its original version refers to the number of transistors in a CPU which has increased at this pace, e.g. from around 36 million in the year 2000 to more than 900 million a decade later. The PC brought computing power to almost all employees desks that two decades ago would have been impressive for mainframe computers and unleashed enormous productivity gains when handling data.

Creative design, growing power of the consumer but not least the capabilities to handle large quantities of data from production planning, marketing and sales channel organisation to warehouse and order management has led to a larger variety of products. This complexity is even subject to dynamic changes. If decades ago in the textile industry people would talk about winter and summer as the two main different seasons then today almost every month comes with more or less modifications to parts of the offer and related logistics.

The internet started initially as a global commutation network and tool of sending messages between scientists. Until today it became much more—not least driven by Tim Berners-Lee who created the idea of websites by combining the concept of hypertext with the transmission control protocol and the domain name system idea in 1989. Jeff Bezos, when he founded Amazon.com in 1994 identified the book as the best product to be sold online because there were so many different titles, people would like to communicate about it and try an online order process. That process well connected with the logistics operations and affordable shipping to private households makes the core of a multi-billion-dollar operation 20 years later.

Global collaboration between suppliers and their customers as well as service providers along the supply chain will be driven by 'big data', the next level of gathering and handling information from further growing numbers of decentralised sources, allowing correlations to identify demand patterns, business trends and opportunities as well as system failures. Existing sources may be combined with ubiquitous information-sensing mobile devices, software logs, images or barcode scans, RFID-tagged data or GPS-position.

As shown for example in the new DHL Delivering Tomorrow report, future developments are difficult to anticipate and even more difficult to transfer to operational business research in logistics—though some major developments can be identified, e.g. by scenario technique (DHL 2012).

- Resource shortage and sustainability;
- Urbanisation and new importance of urban logistics systems;
- Security concerns and problems within international transport systems;
- Importance of demographic changes and knowledge management concepts;
- Technological innovation as e.g. RFID and GPS implementation as well as the internet of things with new steering mechanisms for logistics systems.

Security requirements in an increasingly threatened environment are already a major task and innovation expectation towards logistics. A tendency to repeat or intensify screening procedures doesn't seem to be the best answer. More likely it is in the best combination of technology implementation—from surveillance to GPS tracking and tracing—and organisational concepts to identify root causes and thus secure trade routes and transport infrastructure worldwide.

The further integration of telematics and *information systems* in operative logistics processes will bring revolutionary changes described among others by the term "internet of things" as many transport objects will become subjects and take over independent information retrieval, analysis and decision capabilities (World Bank 2007). This will bring new processes as well as qualification requirements as personnel will be less and less integrated in physical material handling and flow tasks but more and more in supervision, steering and exceptional event management tasks (IPCC 2014).

Track and trace supported by cheap and reliable barcode readers in sorting facilities as well as location services from global satellite systems form the backbone for both—enhanced customer service as well as quality management tools within logistic network operations.

## 6 European Research and Innovation Initiatives

Different developments during the last decades face the European transport arena: First the increasing *globalisation* brought longer and more complex transport and supply chains in Europe. Second the market *liberalisation* in Europe in waterborne, rail and road transport brought an increasing competition, as well as global players and alliances—competition from a huge number of small and medium sized enterprises (SMEs) with different geographical sphere of activity. Several European countries, especially The Netherlands and Germany, are among the global leaders in the logistics sector, supported by excellent ratings, e.g., from the World Bank regarding the transport infrastructure and performance (World Bank 2010, 2012).

Interacting with the business practice development also the traditionally strong business science in the fields of production and transport as well as operations research was strengthened. Naturally, strongholds are in areas close to large ports and long established industrial activities, in Germany, e.g. in the state of North Rhine-Westphalia (EffizienzCluster LogistikRuhr 2012). The EffizienzCluster LogistikRuhr was one of the larger research initiatives within the German national "Leading Edge Cluster Competition" to secure a leading position. The innovations foreseen in logistics are connected to economical and technological developments as well as with infrastructural and political circumstances. The work of the Cluster is determined by three parameters:

1) To protect the environment and resources. The limitation of resources and the hazards for ecological systems have caused a change of thinking in business and society.

2) To guarantee the supply of urban systems. The trend towards urbanisation is increasing, also as a result of demographic change. More goods will have to be distributed into conurbations and city centres using infrastructures which are already stretched to the limit.
3) To maintain individuality of a society. The diversified consumption and leisure behaviour of individuals have led to increasing complexity asking for new solutions to fulfil the requirements of consumers.

In The Netherlands, the Dutch Institute for Advanced Logistics (DINALOG), supported by national government funds, has drawn up a strategy to reinforce the international position of the national logistics and supply chain management industry. Core elements are cooperation and exchange in the field of R&D with international partners and attracting direct and indirect international investment and knowledge workers to help organising and facilitating export of Dutch logistic and supply chain knowledge and competencies. One of the central themes of DINALOG is the "Cross Chain Control Centre" (4C). The idea behind 4C is the creation of economies of scale thanks to cooperation across companies and chains. A 4C is a control centre where several complex worldwide supply chains are coordinated and directed. This concerns the bundling and control of physical goods flows, information flows, financial flows and data management, resulting in, e.g. improved overview, better harmonisation and bundling of activities; savings in costs by combining loads and decreased pressure on the environment; new knowledge and new business activity with more jobs; improved attraction of The Netherlands on foreign companies.

National Clusters in Europe, such as DINALOG, EffizenzCluster Logistik led by the Fraunhofer IML or CNC-LOGISTICA, the National Centre of Excellence in Logistics, led by the Zaragoza Logistics Center (ZLC), a research institute established by the Government of Aragon in Spain in partnership with the Massachusetts Institute of Technology and the University of Zaragoza in 2003, are just examples and some of many more stakeholders facilitating exchange between logistics research and industry in Europe.

With the increasing importance and complexity of logistics research, dedicated institutes were set up to improve operational management of organisations. These institutes have favoured an open environment making it easier for companies to work with them, establishing the right links between research and industry and starting virtuous collaboration in research and innovation. This approach substantially supports transforming research results into practical cases for implementation, and in this way contributes to closing the gap between research and market implementation. Research institutes will continue their role to act as the lubricant for the whole ecosystem around education and innovation in the areas in which they develop their activities, and possibly in 10 years real breakthrough innovations can be realised. A major breakthrough may be triggered by changing business (e.g. e-commerce, energy and environment) or by a strong core group of industries moving towards a new, more efficient performance level to meet the infinite demand for 24/7 services. The current attention for the Physical Internet represents such an initiative.

Within the Seventh Framework Program of the European Commission, around 200 projects, funded as part of the sustainable surface transport research agenda between 2007 and 2013, were related to topics such as, greening of surface transport, encouraging modal shift and decongesting transport corridors, ensuring sustainable urban mobility, improving safety and security, and strengthening competitiveness.

Significant improvements have been achieved in many projects: vehicles, vessels and rail operations became more efficient; intermodal networks have been expanded across Europe; ICT-application have been developed and were successfully applied for planning, routing and operational optimisation in general. Intermodal logistics offers optimisation potentials as it combines the strength of more than one mode. While e.g. trucks are been thought of as the most adaptable mean of transportation, in particular railway and ship offer a high efficiency with bulk good transport, as well as cost-effectiveness, transport security and environmental compatibility. Hence, intermodality has been promoted through European transport policy and is still an area of ongoing innovation and opportunity.

However, recent discussion e.g. within the newly formed European Technology Platform on Logistics (named ALICE since June 2013), emphasis the need of a logistics and supply chain planning and control approach: By joining the shippers and logistics service providers perspectives and information basis decisions will be enabled that allow redesign of supply chains and trigger much more efficiency gains that achievable within the transport sector itself (The WINN Consortium 2012). The European Conference of Transport Research Institutes (ECTRI) position on the second work programme of the Transport Challenge in Horizon 2020 points in the same direction when calling for a new guiding theme "Towards an integrated transport system" and "systemic research areas of urban mobility and logistics" (ECTRI 2014).

## 7 Outlook

To keep jobs in Europe, to ensure the performance of trade and industry as well as individual mobility and consumption, member states as well as companies have to invest further in research and infrastructure. Logistical capabilities will be crucial to the global economy, as argued by the World Bank and supplemented by the Logistics Performance Index studies since 2007 (United Nations 1999).

Growth of global trade in general and online retail in particular, new technologies—from autonomous vehicles to 3D printing—and new mobile-app-based transportation business models are among the many drivers of change of the world of transport we know today, and "still, the transport system is not sustainable. Looking 40 years ahead, it is clear that transport cannot develop along the same path." the European Commission's White Paper on the Roadmap to a Single European Transport Area pointed out in 2011 (COM 2011).

Further research integrating the logistics and supply chain planning view and resulting abilities with feasible transport solutions and business models is very likely to take Europe's logistics and freight transport operations to a next level. Sustainability issues are pressing and will require corporate attention, smart governments and consensus within society to exploit resources with responsibility and stay competitive in a global economy.

## 8 Structure of the Book

This book addresses the main challenges affecting modern logistics and supply chains. It investigates logistics from a comprehensive viewpoint embracing the entire supply chain. The key findings presented are based on both extensive research and on business cases. The book contains nine chapters and is structured as follows.

Chapter "Logistics trends, challenges and needs for future research and innovation" presents an overview of the key trends and challenges of logistics and supply chain. It was found that increasing globalisation brought longer and more complex transport and supply chains, and that the market liberalisation in surface transport brought an increasing competition. In addition, the chapter addresses the needs for future research and innovation and related initiatives in Europe.

Chapter "Business models for advanced ICT in logistics" addresses ICT for logistics, especially from the perspective of business models. Technologies are enablers for sustainable logistics and supply chain management. ICT creates new opportunities for co-operation and competition. This is a strong need to look into business models, their evolvement to cope with revolution of technology. The focus of the business models is on the key elements that characterize the value-creation links between the involved logistics actors. The chapter investigates the traditional concepts of business models, and the evolution of business models considering the future business environment. Two case studies are presented.

Chapter "Future-proofing supply chains" presents the needs and approaches for companies to strengthen their competitiveness in view of the rapidly changing environment and the changing customer behaviour. The chapter explores a diagnosis tool to assess the supply chain of a company and to evaluate the gap with the upcoming societal, consumer and logistics challenges. The gap analysis provides a strong basis for an action plan to appropriately adapt the current supply chain. The developed tool may help to measure whether the applied business models in the sector are resilient enough to operate on a medium to long term strategy for continuous value creation.

Co-operation and competition are not mutually exclusive, but require confidence, and an economic and legal framework. Chapter "Gain sharing in horizontal logistic co-operation: a case study in the fresh fruit and vegetables sector" presents one of the main solutions for sustainability of logistics and supply chain through horizontal collaboration. Companies start to notice the needs, benefits and new challenges of setting up a logistic co-operation. The chapter targets the challenge of dividing the total coalition gain among logistics actors, and examines the impact of defining gain sharing from a short-term and a long-term perspective. A real life case study of fresh produce traders is applied.

Logistics means also the use of physical infrastructure. In general, not much attention is paid to inland waterways. Yet, a system wide model for inland waterway transport will allow analysis of the network-wide impact of synchronisation efforts, of congestion measures and of alternative priority rules and lock planning algorithms. Chapter "Scheduling serial locks: a green wave for waterbound logistics" studies scheduling serial locks and their impact on inland waterbound logistics. Transferring ships through a series of locks based on their requested time of arrival at a destination, has potential to generate a green wave for waterbound logistics. The results of this research have been applied at the Port of Antwerp.

Chapter "Supply chain network design: tackling regulations, lead time and cost-efficiency" takes the reader to Africa, runner-up in the global economy. It is also special as it is abundant with resources, such as oil, minerals and agricultural products, the trade and transport of which require sound logistics. The challenge is how one can design a robust supply chain network in a continent still marked by many political and cultural obstacles. The chapter explores relevant challenges and solutions for supply chain network design. It is based on a case study of the entire supply chain for an oil and gas industry, following several criteria related to location, stability, lead times, profitability and intelligent hub. Various scenarios are investigated. In addition, it provides a set of recommendations regarding to location of the hub, renting equipment, modal transport and benchmarking.

Urban freight transport planning and supply chain network design is of a complete different order of magnitude. Chapter "Urban logistics: multi-modal transportation network design accounting for stochastic passenger demand and freight logistics" focuses on urban logistics by taking a holistic view, in which, for instance, passenger and freight transport in an urban network are no longer considered separately. The chapter presents a bi-level optimisation model by considering multiple transportation modes, stochastic passenger travel demand and logistics in the urban area. It also illustrates effectiveness of the approach, with an illustrative example and a set of benchmark problems in urban logistics.

Chapter "Tango without the dancefloor? The forgotten role of the public sector on logistics" addresses a special issue on logistics policy in Europe and public procurement. It provides a comprehensive overview of the ways in which public authorities and the government in the wider sense influence and enable the logistics business. It argues that the role of the public sector has become more prominent in recent years. Better coordination and collaboration between the public and private sectors are needed.

The logistics sector is a backbone industry for economic growth. However, it also has negative impacts on the environment, which is one of the dimensions of sustainability. For sustainable logistics, it is essential to mitigate such negative impacts. Therefore, a reliable and consistent approach is needed for measuring and calculating environmental impacts. Chapter "Towards a harmonised framework for calculating logistics carbon footprint" explores a harmonised framework for calculating the carbon footprint of logistics.

## References

Clausen U, Hesse K (2012) Eco-efficient logistic processes. In: Information Technology Methoden und innovative Anwendungen der Informatik und Informationstechnik, February 2012, pp 24–32

COM (2011) 144 Final. White paper: roadmap to a single European transport area—towards a competitive and resource efficient transport system. European Commission, Brussels, 28 March 2011

DHL (2012) Delivering tomorrow—logistics 2050, A scenario study. DHL, Bonn

Drewry (2011) Container market review and forecast. Drewry, London

ECTRI (2014) ECTRI (European Conference of Transport Research Institutes) Position on the second work programme (2016-2017), Brussels, July 2014

EffizienzCluster LogistikRuhr (2012) http://www.effizienzcluster.de

International Energy Agency (2014) Key world energy statistics. IEA, Paris

IPCC (2014) Climate change. Synthesis report. IPCC (Intergovernmental Panel on Climate Change), Geneva. http://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_LONGERREPORT_Corr2.pdf

Meteo World (2014) CO2 crosses 400 ppm threshold throughout northern hemisphere. http://www.wmo.int/pages/publications/meteoworld/CO2Crosses.html

United Nations (2013) World population prospects: the 2012 revision. Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, June 2013. United Nations, New York, NY

WINN Consortium (2012) Logistics innovation for a more sustainable and competitive industry—Towards a European technology platform logistics (version 08). WINN (European Platform Driving KnoWledge to INNovations in Freight Logistics) Consortium, Brussels

World Bank (2007) Logistics performance index 2007. World Bank, Washington, DC

World Bank (2010) Logistics performance index 2010. World Bank, Washington, DC

World Bank (2012) Logistics performance index 2012. World Bank, Washington, DC

# Business Models for Advanced ICT in Logistics

**Valentina Boschian and Paolo Paganelli**

**Abstract** This scientific work explains how ICT together with an innovative business approach may enhance supply chains. The presented results derive from the application of a novel methodology developed to study the evolution of the business models of different business actors belonging to a business ecosystem focused on co-modal logistics networks. Each type of actors is pursuing its own value system on the basis of the key elements that identify and characterize the nature of its activities and business. The focus of the business models is on the key elements that characterize the value-creation links between the involved actors in the proposed Logistics Reference Value Chain. The presented work focuses on broadening and exploring the traditional concepts of business models showing their evolution when considering the future business environment. Two cases studies are presented to show in practical terms the evolution of the business models of the involved logistics actors in a business ecosystem and to present concrete examples from industries.

## 1 Introduction

Corporate managers traditionally have viewed logistics as a mandatory cost bucket. But top-performing companies now recognize that supply chain and logistics can be more than that: it can be the source of competitive advantage. This strategic shift opens up significant growth opportunities for logistic services providers, with winners using different paths and business models to foster growth (Rousseau et al. 2012).

As customers enter new markets, especially in emerging economies, they are demanding much more than traditional transportation and warehousing services from their freight forwarding and contract logistics providers. The ability to offer new, value-added services such as warranty processing, returns management and

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light manufacturing is now a differentiator, as is providing services such as customs and insurance brokerage, and trade and transportation management (Accenture 2012).

Therefore, along with warehousing services (picking up, packing and labelling), contract logistics suppliers have extended their traditional core into extra value-added services, such as postponed manufacturing (light assembly, kitting, manufacturing and quality control), and even payment and customer management (Rousseau et al. 2012).

Almost all of the major third-party logistics players evolved from a core business into operations with diverse activities. For example, Kuehne & Nagel started out in freight forwarding and Norbert Dentressangle began in road transport. However, these players take significantly different approaches, leading to several strategies (Rousseau et al. 2012).

As markets become more competitive it is often necessary to increase service divergence, i.e. differentiate services to differing positions by offering a greater variety of services and channel options for the customers. “One size fits all” does not really need to be the solution for all relationships with supply chain members (Dyer et al. 1998; Lambert and Cooper 2000). Scenario changes during the past decade have brought radical transformation in the European logistics service market. One of the major drivers has been the deregulation of the European transport market. Mergers and acquisitions in the logistic services industry in Europe have led to a market with a few dominant players with global coverage and diversified activities, and a large number of small and medium-sized service providers with a regional and a more specialized service portfolio (Bask et al. 2010).

Therefore, to stay ahead in the modern global marketplace, business organisations must constantly look for innovative strategies to improve their competitiveness. Continuous technological advancement has assisted industries to revolutionise the way they operate and conduct their business. Technology enables service firms to improve their efficiency and effectiveness, and to enhance their services. The rapid growth in information and communication technologies (ICTs) over the past 20 years has been a major driver in the growth of service industries and continues to be the main engine for innovation within the services sector and beyond, transforming in many ways how goods are produced, advertised and distributed (Chapman et al. 2002).

Emerging ICT-based paradigm force companies to reassess the opportunities and challenges, and to re-examine how they conceptualise and conduct their business. Leading organisations today will therefore have to adopt innovative strategies and practices if they are to operate effectively in this new global market (Chapman et al. 2002).

A further transformation highly impacting the logistic sector is the challenge to become environmentally sustainable, imposed by the increasing global awareness and commitment to preserve resources and reduce emissions (Mason et al. 2007). These developments in turn require logistic firms to re-evaluate the value propositions they present to customers in many sectors, as the supply-side driven logic of the industrial era has become no longer viable (Teece 2010). Both citizens and companies become more and more aware of the impact of freight traffic on the environment and quality of life. This change is forcing the logistic industry to offer sustainable transport solutions based on collaboration (Mason et al. 2007). Demand patterns are changing as globalization and e-commerce are enforcing a practice of "selling less of more" (Anderson 2008), where consumers have access to an increasing variety of options and personalized solutions. This implies that new freight services should evolve rapidly to meet the changes in consumer behaviours, adding flexibility and eco-efficiency as points of attraction.

Therefore, to properly address the market transformation and evolution, logistic companies have to consider and define new business models as alternative to their current approaches and practices. This means figuring out how to transform the organization to address customer needs more efficiently, but also how to provide new services offering customers both traditional and new forms of value (e.g. environment-friendly logistics).

The essence of a business model is in defining the manner by which the enterprise delivers value to customers, entices customers to pay for value, and converts those payments to profit. A business model articulates the logic and provides data and other evidence that demonstrates how a business creates and delivers value to customers. It also outlines the architecture of revenues, costs, and profits associated with the business enterprise delivering that value (Teece 2010).

Since defining new business models can be difficult, (Chapman et al. 2002), there is a need for structured approaches and tools to manage the evolving and complex aspects of new business models.

Starting from this assumption, the goal of this work is to present a novel structured approach that treats business models in logistics as a variable and not a constant element. For this purpose, we explore the concept of a business model by addressing the several core questions that the majority of business model researchers deal within their models, but we do not consider that, as it is done usually (Seddon et al. 2004), the answers to these questions are fixed. Rather, we investigate the new opportunities that can be captured by taking into account variable answers to these questions, forming the essence of business model innovation. The proposed approach allows to systematically analyse the possible evolution of the current business model of logistic companies, their clients and suppliers, in relation to the introduction of business and technological innovation.

The presented results show the evolution of the business models of actors and users involved in the logistic value chain. In particular, the evolution of the roles of the logistics actors are deeply analysed and presented within a business ecosystem and moreover results from industries are described and detailed.

The paper is organized as follows: Chapter "Business models for advanced ICT in logistics" presents the main references and contextualizes the addressed topic in relation to the analysis of the business models, especially in the logistics sector; Chapter "Future-proofing supply chains" introduces and defines the core concepts related to the Logistics Reference Value Chain and presents the current business models of the main actors there involved; Chapter "Gain sharing in horizontal logistic co-operation: a case study in the fresh fruit and vegetables sector" describes the proposed approach and methodology; Chapter "Scheduling serial locks: a green wave for waterbound logistics" presents the main results obtained by applying the proposed methodology in the selected case studies and finally Chapter "Supply chain network design: tackling regulations, lead time and cost-efficiency" concludes the paper, discusses the presented results and presents the next steps for future research.

## *1.1 Relevant ICT Solutions in State-of-the-Art*

The main goal of this section is to analyze the most modern Information and Communication Technologies relevant to supporting the implementation of key logistical capabilities. The objective is not to provide a general survey of the technology market but to concentrate the attention on solutions strictly related to logistics business models innovation, grouped into three main categories outlined in the following paragraphs.

### 1.1.1 Logistics Connectivity and Interoperability

The goal of this category of solutions is to facilitate interoperability between the different logistics actors without requiring preliminary alignment of processes and ad-hoc connectors. There are different technologies, standards and solutions that provide facilities for the implementation of runtime loose-coupled integration of systems and platforms:

- Event-driven Programming

  The wide and fast adoption of technologies like Ajax and Node.js for the implementation of services hosted on the web has been the basic contribution to the new rise of the distributed event approach for programming. At the base of event driven architectures there is the promotion of applications and systems, which transmit events among loosely coupled software components and services. These loosely coupled objects treat changes in states as events to be produced, published, detected and consumed allowing a loosely coupled communication within the architecture. Event-driven architecture can fits well also as a complement to service-oriented architecture because services can be activated by triggers fired on incoming events. These events can be generated by user actions, sensor outputs or messages coming from other objects or services. This architecture is extremely loosely coupled and allows extreme scalability because the events do not know about the consequences of their cause and so, for instance, an RFID sensor fires an event when something happen but the sensor itself does not need to know that other objects will add information as a reaction to this event.

- Standards and semantic technologies

  In the logistics field, sectorial standards have been developed in separate domains (e.g., TAF-TSI for rail, e-Maritime or IATA e-Freight). Attempts to build a common denominator standard across transport modes are on course, under the impulse of research projects such as e-Freight.

  The semantic technologies aim at solving the interoperability issues among standards. In particular the different semantic standards and tools can help solving three main issues: (i) definition of common knowledge (domain ontology definition), (ii) the annotation of resources using the knowledge defined by an ontology, (iii) semantic reconciliation for translation of information from one structure to another structure. The combination of these three capabilities solves the problem of sharing heterogeneous information.

  The most widely used languages for ontologies definition are: RDF (Resource Description Framework), born for conceptual description of web resources and it can be used as a general method for modelling information stored on the web, and OWL (Web ontology Language), based on a RDF serialization. Semantic annotation enriches the unstructured or semi-structured data with a context that is further linked to the structured knowledge of a domain, e.g., SAWSDL (Semantic Annotations for WSDL and XML Schema, W3C Recommendation).

### 1.1.2 Intelligent Vehicles and Infrastructures

The connection of data sources representing all the resources involved in a logistic service allows the specification of the so-called *Intelligent Cargo* (Euridice Project 2008). The *Intelligent Cargo* is composed not only by smart devices able to provide automatically information on the status of the cargo itself but also by an IT infrastructure that put this information in relation with the status of the entire logistic context in order to produce useful information from all the data coming from different sources. Outcomes of the Euridice Project (2008) are the foundation followed by iCargo for what concern *Intelligent Cargo* technologies. The information collected by the *Intelligent Cargo* technologies applied by iCargo (iCargo Project 2012) can be merged with different and more general transportation infrastructures, in order to achieve integration with public transports environments and public authorities. This allows faster and easier implementation of advanced freight transport approaches, such as platooning and advanced routing and parking of freight vehicles.

From the technical point of view, initiatives like CALM (Håkegård et al. 2011) and CVIS (Cooperative Vehicle-Infrastructure Systems) provide architectures and infrastructures for the vehicle communications while the application of agent technologies provide scalability in the context of complex networks like the ones managed by iCargo.

The ideas from this architecture, and the way of organizing cooperative services have been taken further in projects as SMARTFREIGHT (Smartfreight Project

2008), FREILOT (Freilot Project 2009), DiSCwise (DiSCwise Project 2011), and INTEGRITY (Integrity Project 2009).

### 1.1.3 Planning and Decisions Support

With the increasing complexity of global and closely linked supply chains the need for comprehensive systems to manage these complex transport chains with all its functional requirements developed in the late 1990s. These systems are called transportation management systems (TMSs).

Key capabilities of such systems are planning, where multimodal transport chains are selected on the basis of given cost and/or time constraints, and monitoring and control execution of the resulting transport processes. Integration of mobile units (in means of transport, loading equipment, etc.) via telecommunication is an important element for management and control.

TMSs generally allow planning, management, control, and optimization of transportation networks and supply chains. Elementary functions of these systems are the order management, scheduling, transport planning and optimization, tracking and tracing, and fleet and resource management.

The product range offered and the capabilities of large providers are often more diverse than that of small companies. In addition, the large providers also provide other solutions, such as Enterprise Resource Planning (ERP) and Warehouse Management (WM) systems (Verwijmeren 2004). Consequently, the large providers normally are targeting larger customers offering a complete package if needed. So far, the number of companies that are offering TMS in addition to ERP and WMS is limited. However, some ERP vendors expand increasingly towards offering TMS capabilities. Usually with increasing functionality of TMS the cost of the overall system is also increasing. The use of appropriate software solutions, especially in transportation-intensive industries, is of growing importance. In recent years, the demand for TMSs increased significantly. This shows that the use of TMS is today almost inevitable (Helo and Szekely 2005). Here, the objectives of the users hardly differ. Regularly high savings of resources and a cost-effective and efficient order processing is the target.

## *1.2 Logistics Business Models in Literature*

Over the past few years, business models have surged into the management vocabulary. The use of the concept of business model increased dramatically during the rise of the so-called ‘digital economy’ period in the 1990s when companies were actively seeking new ways of doing business. Now, companies of all sorts in virtually every industry rely on the concept as well (Shafer et al. 2005).

While it has become quite fashionable to discuss business models, many executives remain confused about how to use the concept. To be sure, many authors have offered definitions of the term business model and these definitions vary from author to author. There is no consensus or mutual understanding in academia on how business models should be defined and what should be included (Bask et al. 2010).

None of these definitions, however, appears to have been accepted fully by the business community, and this may be due to emanation from so many different perspectives (i.e., e-business, strategy, technology, and information systems), with the viewpoint of each author driving term definition; by peering through different lenses, authors are seeing different things (Shafer et al. 2005).

In general terms, the business model concept offers managers a coherent way to consider their options in uncertain and fast-moving environments. A good definition is proposed by (Shafer), where a business model is defined as a representation of a firm's underlying core logic and strategic choices for creating and capturing value within a value network.

A business model of a company can be seen as an essential locus of innovation, and has the potential to disrupt existing industry structures (Amit and Zott 2001; Markides and Charitou 2004; Teece 2010). Business models can also be used as an analytical tool for the description of business activities of a company (Sinfield et al. 2011). Business models help in getting everyone in the organization aligned in producing the kind of value the company wants to create. Therefore, the concept has an enormous practical value (Magretta 2002). A business model is a holistic concept, which embraces elements such as pricing mechanisms, customer relationships, partnering and revenue sharing (Osterwalder 2004; Osterwalder et al. 2005). Business models can be seen as focusing on the activity-system side of how a firm creates economic value (Shafer et al. 2005).

The business model approach has become popular in recent years (Osterwalder et al. 2005; Pateli and Giaglis 2003), partly because continuously changing business processes, practices, and operations have to meet the needs of the marketplace.

However, business models are relatively poorly investigated in research (Linder and Cantrell 2008; Osterwalder et al. 2005). Organizations can compete in the global environment by utilizing world-class electronic communication systems and by operating common simplified and standardized processes (Hamel and Prahalad 1989).

According to Barratt (2004), separate supply chains can be designed to meet the specific needs of the various customer segments if customers can be segmented according to their buying behaviour and service needs. It will be of considerable interest to look at the supply chain relationships, development of service processes, differentiation of services, and the channel interfaces from the perspective of supply chain management (SCM).

The types of value chains or business models are strongly dependent on the basic strategic choices made by companies—for example, cost leadership, differentiation, and focus strategy (Porter 1980). The drivers behind business model changes have been listed often, and the most important factors include globalization, open markets, introduction of new technology, the Internet and information and communication technology in general (Amit and Zott 2001; Chesbrough 2007;

Delfmann et al. 2002). It seems to be difficult to prioritize these drivers or to place them in any specific order.

The Internet not only provides companies with a new channel in which to meet their customers, but also platforms for cooperation between companies and customers in developing and testing new services, technologies, and products. In addition to conventional channels, companies are able to choose among several digital channels, facilitating different strategic positions for services. This multichannel environment poses new challenges, but also offers new opportunities (matching service strategies, business models and modular business processes).

On numerous occasions, researchers have brought up the differences and interconnections between strategy and business models on the one hand and business models and business process models on the other (Osterwalder et al. 2005; Seddon et al. 2004; Stahler 2002). However, there is an increasing importance to increase research regarding interconnections of all these three levels: strategic level, business models, and business processes. Osterwalder (2004), states that strategy, business models, and process models address similar problems in different business levels. Strategy focuses on the corporate/group and planning level, business models on the business unit and architectural level, and business processes on the functional and implementation level.

Depending on the complexity and specifics of the client's supply chain, its logistics requirements can vary greatly, creating different sales opportunities. In the retail sector, for example, logistics are primarily local, with less demand for value-added services such as warehousing and trucks. Cost is a primary consideration, limiting opportunities for logistics providers to sell services that combine multiple activities such as freight, logistics and trucks (Rousseau et al. 2012).

High tech requires more complex, global logistics, with faster lead times and increased security and safety for products. Offerings are evolving from standard logistics with warehouses to flows logistics with cross docks, a technique that speeds up shipping while reducing the cost (Rousseau et al. 2012).

In the evolving logistics marketplace, winners understand that there is no single path to success. They overtake competitors by selecting an organizational model that best supports their corporate strategy. They also ensure that the strategy matches their targeted customer segments. To increase their competitive edge, leaders develop insights into customers' needs and purchasing behaviours. The end result is a highly focused organization with a well-defined business strategy, designed to deliver sustained growth and profitability (Rousseau et al. 2012).

The following are some of the important lessons about high performance from which all players in the freight forwarding and contract logistics industry can benefit (Accenture 2012):

- Flexible business model. The high performers know that time to market is critical in their industry—and they have the flexibility to respond with speed and agility to their customers' need for convenience. High performers have established new ocean freight links to growth geographies such as Africa. And they have opened multiple new service links that span the global trade routes over which they dominate.

- Deep expertise in key customer industries. Industry knowledge is growing in importance as customers extend their supply chains in response to globalization. High performers have been leaders in developing extensive expertise in the industries they serve, going well beyond traditional transportation and warehousing solutions. Increasingly, logistics companies are strengthening their ability to collaborate and are better aligning themselves with customers' operations, processes, industry know-how and technology.
- Using IT to maintain 360-degree control. The high performers have moved well beyond using IT merely as an enabler of internal process management. Instead, they leverage their proprietary customer-facing technologies to empower their customers, offering them end-to-end visibility across the entire supply chain. Important to on-going success will be the ability to develop more "intelligent" services, more dynamic planning and increased alignment with customers' operations and processes.
- Supply chain visibility remains a top operational priority for large customers. Customers generally struggle to achieve a unified picture of their supply chains because of the legacy information systems designed to operate within a single company, not across a network of companies. Thus, the ability to share real-time information with key customers, suppliers and partners has become critical in the freight forwarding industry.

Another example of a situation that requires innovative business models is the collaboration between logistic services providers and shippers. Obviously, technical innovations are necessary for cross-chain collaboration. This can only work if new collaborative business models are developed to solve issues, such as: the fit between collaborative and individual business models, the dynamics of how to develop and evolve a joint business model, the influence of external factors shape that joint business model development, acceptance of business models across organizational boundaries, processes and procedures used to develop joint business models (van der Sterre 2011).

The key concept is that shippers, logistic firms and infrastructure managers take coordinated and aligned action such that, given the aggregated demand for transport, the optimal modality is chosen such that the individual objectives for the relevant actors are fulfilled. In a synchromodal transportation system, shippers and carriers are able to dynamically switch between modalities, bundle and aggregate freight and vary in service. This in turn will lead to higher load rates, improved lead-times, more reliable service-provision, less vehicle movements and more sustainable transport with lower integral costs. In summary, synchromodality can be seen as a next step after co-modality, with a focus on the dynamic interaction between shippers, service providers and infrastructure managers. As synchromodality will require innovations in and an improved alignment between the operations of all these agents, new logistic business models have to be defined (van der Sterre 2011).

As a conclusion, it is noteworthy to underline that the range and scope of logistics services have clearly extended during the recent decades. Consequently, a multitude of new business models in different strategic positions have emerged in the market (Bask et al. 2010).

## 2 Analyzing the Impact of ICT on Logistics Business Models

To analyse how ICT innovations contribute to business models evolution in the logistics industry, in this chapter we propose a structured approach based on:

– The identification of the key business players in the logistics chain, which are their goals and their relationships with other players.
– The analysis of the value delivered by innovative ICT solutions to each of the business players.

### *2.1 Actors in the Logistics Value Chain*

A value chain is a set of activities and processes tracing the stages of a product from raw materials to the final customer. Looking at the value chain as a whole requires looking at the product from the point of view of the customer—with companies providing links in the larger chain process, not merely as manufacturers of specific components (Chapman et al. 2002). This is a subtle but significant shift in approach, and means that improving the overall value to the end customer requires suppliers and manufacturers in the chain to seek avenues for collaboration, rather than continual competition, as also analyzed in the Sect. 2.2.

The value-chain perspective highlights interdependence among companies in a common value chain. Intermediaries become partners who deliver value to the customer, and the boundaries between organizations become more fluid as key inter-organizational business processes become more integrated. Information flows more freely along the channel and inter-company relationships broaden out to embrace logistics, merchandising, and product development—rather than simply being focused on purchasing and selling (Ernst & Young 1999). The focus has had to shift from activity centered on individual firms to activity involving the value chains and clusters within which enterprises are embedded. This can be applied to the prevalence of logistics services throughout the supply chain, and reinforces the need for networks (Chapman et al. 2002).

Logistics firms need to place considerable importance on relationships and networking. Critical linkages exist with other firms both up and down the supply chain, and also with firms outside the supply chain. Logistics firms should develop and maintain long-term strategic alliances with partners to improve performance in the areas of product handling, product tracking, information flow technology, and other product and process advancements. These, in turn, enhance customer satisfaction and firm performance (Epatko 1994; Schilling and Hill 1998; Shin et al. 2000; Vonderembse and Tracey 1999).

The organizations considered in the present work are the actors and users involved in the provision of door-to-door logistic services in the new market scenario depicted in the introduction, i.e., services that:

– cover an entire supply chain or a significant portion of it,
– aim at improving consumer service, cost-effective and with less environmental impact,
– combine services through different transport modes and providers.

This scenario is depicted in the proposed Logistics Reference Value Chain, illustrated in the Fig. 1 below. The value chain is an ideal representation of the customer-supplier relationships between organizations participating in the delivery of door-to-door logistic services.

The following categories of users companies are included:

– the *Logistic Service Client* (LSC) is the user purchasing the door-to-door service solution, typically representing a manufacturing or distribution company. Along its traditional objectives of competitive performances and cost, the LSC is interested in improving the environmental efficiency of its supply chain;

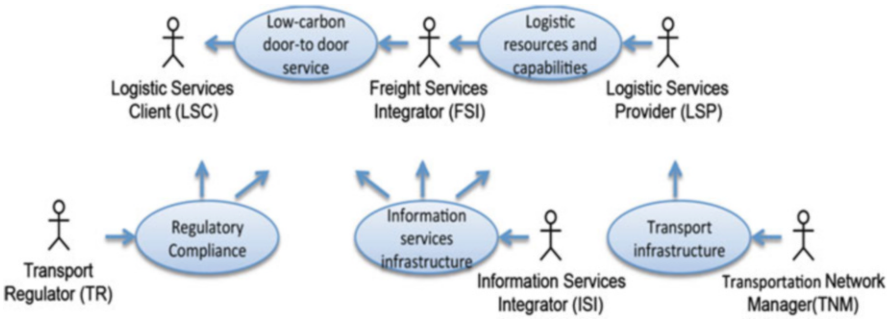


**Fig. 1** Logistics reference value chain

– the *Freight Service Integrator* (FSI) is the user providing the combined door-to-door service to the LSC, typically representing a freight forwarder, a 3PL company or the LSC itself through its logistics department. The FSI needs to integrate, plan and coordinate different logistic services into an effective and efficient door-to-door solution;
– The *Logistic Service Provider* (LSP) is the user providing transport and logistic services contributing to the door-to-door solution like, e.g., carriers for the various transport modes, handling and warehousing companies. The LSP needs to make its transport resources accessible and well utilized when participating in co-modal door-to-door chains;

The three categories (LSC, FSI, LSP) are ideal representations of users relevant only from a functional viewpoint, i.e., to represent functions that are currently performed in the door-to-door services. We are aware that the real market configuration is far more complex, and that no single company can fit in just one role. So the actual configuration of the Reference Value Chain will not impose the schema shown in Fig. 1 but will allow for flexibility, for example a LSP can directly deliver to the LSC a single-mode solution competing with combined door-to-door solutions, or the LSC itself can play the integrator role.

The concrete configuration of the value chain will depend on the evolution of the business models, which will be largely affected by the possibilities offered by information technologies and their actual adoption by the industry. For example, a long-term scenario might see the FSI role disappearing from the market as new technologies will empower any client to effortlessly and transparently combine and manage the LSPs. As it has been happening in other markets, technological evolution will diminish the role of intermediaries, as services demand and supply can be matched on-line, instantaneously and without administrative burdens.

There are also three supporting roles in the Reference Value Chain, representing organizations not directly involved in the provision of logistic services but supplying the physical, information and regulatory infrastructure required by these services:

– the *Information Services Integrator* (ISI) represents the organizations providing the information infrastructure required by the LSC, FSI, and LSP to integrate the logistic services. The ISI role also provides the link to various providers of software services, for example planning or greenhouse gas estimation functionalities offered in Software-as-a-Service (SaaS) mode;
– the *Transportation Network Manager* (TNM) represents the organizations in charge of managing of the transportation infrastructure sustaining the door-to-door flow like, e.g., rail undertakings and city traffic managers. These organizations are not directly involved in logistic services but exchange traffic and infrastructure status information (static or dynamic) with LSPs, to optimize infrastructure usage and reduce environmental impacts;

– the *Transport Regulator* (TR) represents the organizations receiving all mandatory reporting and checking if reporting has been carried out, in order to ensure that all services are completed according to existing rules and regulations. The Transport Regulator has the responsibility of the necessary clearance procedures (security, compliance) for the goods.

As providers of support infrastructure, the information services integrators and related IT companies will have the general benefit of developing a new business in a promising emerging sector.

Transport regulators and network managers will have indirect benefits, i.e., benefits induced by the increased diffusion and the improved management of door-to-door logistic services.

## *2.2 Value Delivered by ICT Innovations*

Referring to the Value Chain introduced and explained above, this Section aims at detailing the value delivered by ICT solutions, as identified in Sect. 1.1, for the three main categories of end users: the LSCs, the FSIs and the LSPs. To this purpose we use the "job to be done" concept, introduced by Christensen et al. (2008). This approach founded on the identification of the "jobs to be done" associated to a particular user role is based on disruptive innovation theories developed at the Harvard Business School, (Christensen et al. 2008), according to which the user does not want to buy a product but he/she wants instead a job to be done. A job to be done is a concept that guides you toward innovation and helps you move beyond the norm of only improving current solutions. A job to be done is not a product, service or a specific solution; it's the higher purpose for which customers buy products, services and solutions. It is very important to highlight that the jobs to be done are completely neutral from the solutions, products and services. While a job to be done remains fairly stable over time, the products and services should change at strategic intervals to increase their value (Christensen et al. 2008).

A way to identify jobs to be done, is by creating a so-called "job tree", i.e., a hierarchical structure starting from high-level jobs, representing fundamental needs that are addressed in several different ways, that are then detailed into more specific jobs, at each level giving more details about particular ways to address the initial high-level job.

All three types of actors in the reference value chain are business organizations, so at a very high level they share a common goal that can be translated in their need **to increase revenues and to keep or grow market share**. This is the starting point to define the jobs for each of these three roles. Starting from this common goal the jobs tree are defined in order to reach the identification of the jobs-to-be-done for each category of actors.

- **Value delivered to the Logistics Services Clients**

  The LSC has the goal to increase revenues and to keep or increase market share in this perspective is translated into: *acquire/keep customers who care for environmental issues and cost efficiency*.

  To define how and why, we use the tree structure illustrated in Fig. 2.
- **Value delivered to the Freight Services Integrators (Freight Forwarders)**

  The FSI has the goal to increase revenues and to keep or grow market share in this perspective is translated into: *providing cost-effective door-to-door services meeting competitively the customer's logistic and environmental targets.*

  To define how and why, we use the tree in Fig. 3.
- **Value delivered to the Logistic Service Providers**

  The LSP has the goal to increase revenues and to keep or grow market share in this perspective is translated in: *make own services available to the FSI, competitively meeting logistics and environmental requirements.*

  To define how and why, we use the tree in Fig. 4.

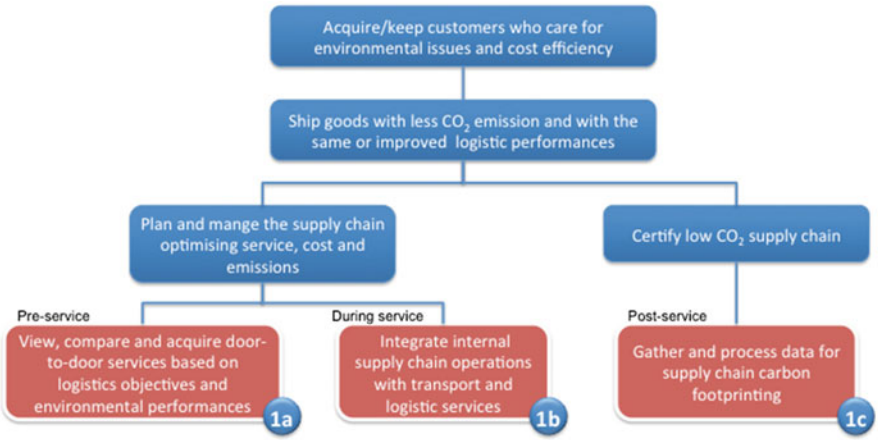


**Fig. 2** Value delivered to LSCs

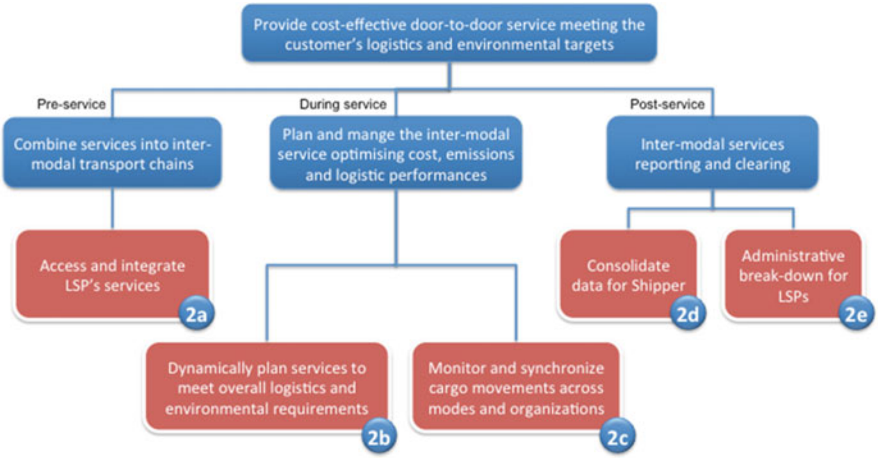


**Fig. 3** Value delivered to FSIs

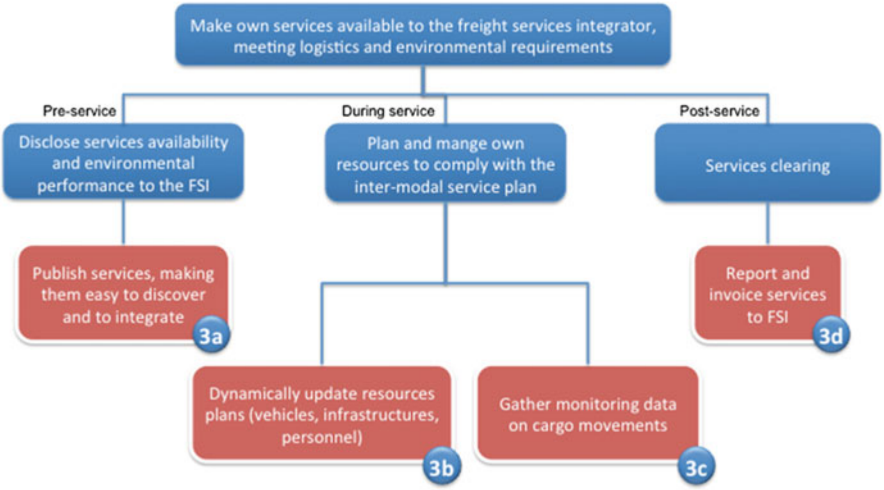


**Fig. 4** Value delivered to LSPs

Table 1 below summarizes the 12 identified jobs for the LSCs, FSIs and LSPs. Moreover it links the jobs to the related ICT innovations and available ICT solutions, as presented above in Sect. 1.1.

**Table 1** Jobs to be done and related ICT innovations

| Actor | Jobs to be done | ICT innovations and solutions |
|---|---|---|
| LSC | 1a—View, compare and acquire transport solutions based on logistics objectives and environmental performances | The shipper has the possibility to choose the transport solution, i.e., the door-to-door service, that fits at best its targets in terms of logistic performance as well as of environmental performances<br>The available ICT solutions belong to the category "Planning and Decisions Support" described in Sect. 1.1, such as advanced TMS |
| LSC | 1b—Integrate internal supply chain operations with ongoing transport and logistics services | Integration of shipper's supply chain plans, scheduling manufacturing and distribution activities, with the door-to-door service plan, e.g., to align supply chain plans with changes occurring during the execution of transport and logistics services<br>The available ICT solutions belong to the category "Logistics Connectivity and Interoperability" described in Sect. 1.1, such event-driven systems aligned with RFID sensors |
| LSC | 1c—Gather and process data for supply chain carbon foot printing | Collection of greenhouse-gas emissions data on the door-to-door logistic service<br>The available ICT solutions belong to the category "Intelligent Vehicles and Infrastructures" described in Sect. 1.1, such as Intelligent Cargo |
| FSI | 2a—Access to and integrate LSP's services | Identification and selection of suitable LSPs based, e.g., service characteristics, emissions generated and performances, and to the integration of these service providers in the door-to-door logistic chain<br>The available ICT solutions belong to the category "Planning and Decisions Support" described in Sect. 1.1, such as advanced TMS |
| FSI | 2b—Dynamically plan services to meet overall logistic and environmental requirements | Generation of the door-to-door transport service plan by dynamically allocating portions of it (e.g., transport legs) to different LSPs based on their capabilities, changing availability and environmental profiles<br>The available ICT solutions belong to the category "Intelligent Vehicles and Infrastructures" described in Sect. 1.1, such as Intelligent Cargo |

(continued)

**Table 1** (continued)

| Actor | Jobs to be done | ICT innovations and solutions |
|---|---|---|
| FSI | 2c—Monitor and synchronize cargo movements across modes and organizations | Collection of information on cargo movements and status in real-time along the route to have a better synchronized flow of goods and activities<br>The available ICT solutions belong to the category "Intelligent Vehicles and Infrastructures" described in Sect. 1.1, such as agents or on-vehicles communication systems |
| FSI | 2d—Consolidate data for LSC | Collection of information on the different services' performances and environmental parameters in order to provide the LSC with a consolidated and coherent picture of the door-to-door transport chain performance and carbon-footprint<br>The available ICT solutions belong to the category "Planning and Decisions Support" described in Sect. 1.1 |
| FSI | 2e—Administrative break-down for LSPs | Separation, in administrative terms, of the overall door-to-door service into portions each individual LSP is accountable for, for service-level reporting, invoicing and payment purposes<br>The available ICT solutions belong to the category "Planning and Decisions Support" described in Sect. 1.1, such as advanced TMS |
| LSP | 3a—Publish services, making them easy to discover and to integrate | Publication of service characteristics, performances and engagement terms from individual LSPs, in ways that make them searchable and comparable for clients, and that allow combination of single services into door-to-door solutions. The available ICT solutions belong to the category "Logistics Connectivity and Interoperability" described in Sect. 1.1 such event-driven systems |
| LSP | 3b—Dynamically update resources plans | Real-time management of transport and logistic resources, based on changes agreed on the door-to-door services plan and on events detected through monitoring of transport execution<br>The available ICT solutions belong to the category "Intelligent Vehicles and Infrastructures" described in Sect. 1.1, such as Intelligent Cargo |

(continued)

**Table 1** (continued)

| Actor | Jobs to be done | ICT innovations and solutions |
|---|---|---|
| LSP | 3c—Gather monitoring data on cargo movements | Collection of information on the movements of cargo and transport means along the logistic network, for events detection and performances monitoring purposes. The available ICT solutions belong to the category “Intelligent Vehicles and Infrastructures” described in Sect. 1.1, such as agents or on-vehicles communication systems |
| LSP | 3d—Report and invoice services | Accounting and reporting of executed services by the LSPs, to match service-level agreements, as well as to meet invoicing and payment terms agreed with the LSC. The available ICT solutions belong to the category “Planning and Decisions Support” described in Sect. 1.1, such as advanced TMS |

# 3 Current Business Models in Logistics

This section proposes a description of the current business models of the companies and users described above in the Logistics Reference Value Chain. The business models are described following the well-know approach proposed by the Osterwalder Canvas (Osterwalder 2004; Osterwalder et al. 2005).

The described current business models refer only to the actors analyzed in the presented case studies in Sect. 4.2. This analysis allows the comparison of the business models at the current stage and then after the implementation of ICT logistics innovations.

## *3.1 Current LSC Business Models*

### 3.1.1 The Current Business Models of Manufacturers

The value propositions is focused on the product quality, functionality, usability, reliability and safety, on the availability on the market and localization of stocks, time of response for customer demand and flexibility, complete and up-to-date catalogue data about product, product brand and producer image.

Key resources of manufacturer are product brand and image, human resources with their knowledge and experience, factory buildings with machines and equipment, non-production external/internal infrastructure, management information and communication systems (front and back office), working capital for production and sale continuity and business liquidity, organizational resources.

| Key Partners | Key Activities | Value Proposition | Customer Relationship | Customer Segment |
|---|---|---|---|---|
| Generally manufacturer partner network include: suppliers/producers, designing and engineering agencies, logistics and transport providers, fleet and warehouses owners, insurance agencies, forwarders and transport integration providers, customs agencies, information system providers (with product catalogue services), e-platforms providers, supply chain or freight services integrators, container/pallet providers, recycling operators. | Key activities of manufacturer business model include generally: production sourcing and purchase of materials, procurement and materials management, transport and supply process, store and warehouse handling, co-production and outsourcing of processes, quality management, account management, maintenance of resources, distribution and transport of products to customer, marketing and promotion. | – product quality, functionality and usability,<br>– product reliability and safety, consumer security,<br>– availability on the market (quantitative, assortment, qualitative and on time) and localization of stocks,<br>– time of response for customer demand and flexibility,<br>– price,<br>– complete and up-to-date catalogue data about product (e.g. construction, materials composition, recipe, technology, etc.) available by Internet and mobile,<br>– information distribution about new versions and modifications of product,<br>– wide range of product line and category,<br>– product brand and producer image. | – personal assistance performed either during: engineering to order and make to order (decoupling point – ETO and MTO), dedicated packaging and distribution, sales and after sales,<br>– dedicated personal assistance with customer in key accounts segment for the sake of sale quantity (or value). | Various sets of customers are segmented on the basis of the product features adjusted to customer needs. Appropriate implementation of various product strategies are oriented on niche, segmented or diverse customer segments (e.g. machinery & metallurgical industry, automotive industry or pharmaceutical industry). |
| | **Key Resources** | | **Channels** | |
| | Key resources of manufacturer are product brand and image, human resources with their knowledge and experience, factory buildings with machines and equipment, non-production external/internal infrastructure, management information and communication systems (front and back office), working capital for production and sale continuity and business liquidity, organizational resources. | | Processes along supply chain are oriented according to product strategy on efficient and cost effective or agile and flexible operations. Manufacturer try to overcome high costs of supply chain operations, uncertainty and variability within company channels. | |

| Cost Structure | Revenue Streams |
|---|---|
| Business model of manufacturer is generally classified as cost-driven with significant emphasis on cost reduction in full supply chain of product supply, production and distribution.<br>Fixed costs caused by fixed assets (manufacturing resources) are dominant in manufacturer cost structure. | Basic and main revenue stream for manufacturers comes from products sale on the market. The contract with customer has also many additional services (e.g. installation, calibration, maintenance and inspection) that increase sale revenue. |

**Fig. 5** Current business model of LSC—manufacturers

Generally manufacturer partner network include: suppliers/producers, designing and engineering agencies, logistics and transport providers, fleet and warehouses owners, insurance agencies, forwarders and transport integration providers, customs agencies, information system providers (with product catalogue services), e-platforms providers, supply chain or freight services integrators, container/pallet providers, recycling operators.

Figure 5 below depicts the nine blocks of the Osterwalder Canvas to describe the current business model of the Manufacturers.

## 3.2 *The Current FSI Business Models*

FSIs integrate, plan and coordinate different logistic services into an effective and efficient door-to-door solution. Key activities include integration of various services (e.g. warehousing, co-packing, co-manufacturing, order picking, handling of goods, cross-docking, multi-modal parks, container terminal operations, forwarding and transport, insurance, consulting), contracting, consolidation and adaptation services in supply chain for order fulfillment, data acquisition, information processing and distribution.

Relationships between FSIs and their customers are identified as combination of dedicated personal assistance in key accounts segment, self and automated services (e.g. cargo monitoring at e-Schenker), community services allowing for a direct

| Key Partners | Key Activities | Value Proposition | Customer Relationship | Customer Segment |
|---|---|---|---|---|
| Partner network of complementary logistics services including - warehouse operators, fleet owners, insurance agencies, haulers, forwarders, customs agencies, providers of logistics information systems (in form of product or SaaS mode) or e-platforms providers, container/pallet providers, recycling operators – to meet customer expectation. | − provide clear end-to-end responsibility for end-to-end set of individual services,<br>− manage the end-to-end system (service, infrastructure, information) availability to the main customer in accordance with the service levels<br>− create, agree and introduce collaborative agreements and operational-level agreements with each major logistics and complementary service provider,<br>− act as integrated performance manager on behalf of the customer with respect to all major service providers, working with them to diagnose and fix root causes of problems and incidents,<br>− monitor, measure and report the end-to-end service. | The main value is the service integration provided through combining of various elements of complex offer for customer such as complex performance and control, full service customization, cost reduction and convenience. FSIs comprehensively integrate the competencies of logistics and supplementary services providers, leading-edge consulting firms and technology providers. Such strategic alliances leverage the skill sets, strategies, technologies and global reach. | − dedicated personal assistance in key accounts segment – e.g. producers, large investors, exporters/importers, building contractors, logistics centres, distributors/large retailers, institutions, recycling operators,<br>− self and automated services – with web services and internet tools,<br>− community services allowing for a direct interaction among different customers and the FSI company. | Various sets of customers can be identified based on the different transport and logistics needs and attributes. All business sectors are covered, including:<br>− Manufacturing, with different level of segmentation by company size, geographical area and product type,<br>− Retail, with similar segmentation as manufacturing,<br>− Public sector for postal services and administration-oriented services. |
| | **Key Resources** | | **Channels** | |
| | Key resources are personnel qualified in management and organization of full supply chain services and taking care of goods to meet customer satisfaction. | | FSIs try to overcome high costs of individual transport and logistics operations, uncertainty and variability within partner's channels by:<br>− improving delivery reliability,<br>− serving a services for many customers with common transport and logistics infrastructure,<br>− forecasting of demand and protecting against the variability in utilization. | |

| Cost Structure | Revenue Streams |
|---|---|
| Business model of FSIs is generally classified as fixed cost with significant emphasis on integration and coordination services aimed at cost reduction along the entire supply chain.<br>The cost account structure is dominated by fixed costs of personnel, information and communication systems (ICT), information services, administrative building and infrastructure, etc.<br>There is a low contribution of variable costs, e.g., for business trips and contracts with additional specialists (consultants, agencies). | Basic and main revenue stream is income from margin sales, derived from value of integration service contract with main customer less the sum of purchased individual services.<br>Total contract value has also many additional components (e.g. information and monitoring costs, cargo and door-to-door freight care, responsibility, fulfillment of special conditions, rapid reaction, etc.) that improve sale revenue. |

**Fig. 6** Current business model of FSI

interaction among different customers and the FSI company. The community platform produces a scenario where information can be shared and problems are solved between different customers (e.g., T-scale, AXIT logistics platform, LogIT 4see Platform).

Figure 6 below depicts the nine blocks of the Osterwalder Canvas to describe the current business model of the FSI.

## 3.3 *The Current LSP Business Models*

LSPs value proposition is focused on high reliability, low price of service or low customer-side cost, short delivery times, customer risk reduction, traceability of cargo and goods, safety and security of product along supply chain, low inventory level and high capacity utilization.

Business model of LSPs is generally classified as cost-driven with significant emphasis on logistics services cost reduction in full customer's requirements supply chain. LSPs cost structure includes both fixed and variable costs: fixed costs for personnel, vehicles and warehouse, can be reduced by economies of scale. LSPs reap benefits on variable costs (e.g., fuel) by effective and efficient operations executed for customer (e.g. effective transport routes planning, optimized truck load).

| Key Partners | Key Activities | Value Proposition | Customer Relationship | Customer Segment |
|---|---|---|---|---|
| − producers, distributors and retailers, institutions, firms or companies doing business in logistics environment (e.g. ship-owners, container providers, insurance companies, custom agencies),<br>− other logistics service providers, logistics resources or logistics infrastructure providers, e.g., warehouse operators, fleet owners,<br>− providers of complementary services necessary for customer fulfillment, optimizing operations and reducing risk. | −Inbound logistics:procurement, purchasing ordering and replenishment planning, arranging inbound movement of materials, parts and/or finished inventory from suppliers to manufacturing or assembly plants, stock and inventory management;<br>− Outbound logistics: supply chain and network organization, warehouse management, transport management, customs warehouse, complaint service. | LSPs can offer better value through various elements of its complex offer such as: high reliability, low price of service or low customer-side cost, short delivery times, customer risk reduction, traceability of cargo and goods, safety and security of product along supply chain, low inventory level and high capacity utilization. | − dedicated personal assistance in key accounts segment (e.g., retailers, manufacturers, large FSIs).<br>− self and automated services (web based services) allowing for self service of producers or retailers.<br>− community services allowing for a direct interaction among different customers and the LP company. | -type of warehousing or kind of warehouse,<br>− type of fleet,<br>− type of cargo,<br>− group of operations depending of special line of business (e.g. activities for production – material handling, co-manufacturing, electronic materials quality control, logistics services include customer support on the phone, development and execution of customer loyalty programs),<br>− areas of logistics services mentioned in previous point (e.g. procurement logistics with procurement centre, distribution logistics with logistics distribution centres, reverse logistics). |
| | **Key Resources** | | **Channels** | |
| | Personnel qualified in logistics service and goods handling (including transport, reloading and stock storing), warehouse buildings and related external/internal infrastructure, terminals, siding, transport fleet, containers, swap bodies, working capital for operations continuity and business liquidity, information and communication systems. | | LPs try to reach its clients through its own channels, by being able to integrate within the partner network to be included in full supply chain services from producer's supplier to final consumer. | |

| Cost Structure | Revenue Streams |
|---|---|
| Fixed costs, for personnel, vehicles and warehouse, can be reduced by economies of scale, e.g., acting on the number and size of service contracts to increase sale margin achieved from square or cubic meter of warehouse or transport space.<br>LSPs reap benefits on variable costs (e.g., fuel) by effective and efficient operations executed for customer (e.g. effective transport routes planning, optimized truck load). | Basic and main revenue stream for LP is income from sales of logistics services and margin sales, based on difference between prices of bought and sold complementary services of other services providers.<br>Purchase contract has also many additional items (e.g. firm or product trademark promotion on the trucks, special conditions for stored or transported goods, rapid reaction for special customers of LP customer) that improve sale revenue. |

**Fig. 7** Current business model of LSP

Figure 7 below depicts the nine blocks of the Osterwalder Canvas to describe the current business model of the LSP.

## 3.4 *The Current ISI Business Models*

The role of ISI is to provide the technological infrastructure for publication, discovery, integration and execution of all the different kinds of services. These services include information representations of physical services, such as transport or cargo handling, as well as "pure" information services, such as intermodal transport planning and monitoring, as well as shipment emissions estimation.

Looking at the current ICT market, and in particular at the present offer of solutions for transport and logistics, there are three broad categories of technologies and services providers who, in the future, might contribute to the fulfillment of the ISI role:

– System Integrators,
– Software and Hardware Vendors,
– Connectivity Providers.

### 3.4.1 System Integrators

A System Integrator's business consists in supporting companies (LSC, LSP or FSI) to build own ICT systems and platforms matching the company's requirements. System integrators have the skills, resources and connections to assist the customer throughout the development cycle, covering all technical, functional and project management aspects of solution development.

A typical system integrator's would approach the problem by supporting the client company, e.g., a large LSC or LSP, to build a own platform where to integrate all services of the client's network of partners. Several existing integration platforms, either provided by large LSPs and Forwarders (e.g., T-Scale platform) or by cargo communities (e.g., Portbase) have been developed as ad-hoc solutions with the support of system integrators.

For example, ATOS offers logistic and ERP systems integration based on the SISLOG product portfolio solution including several software solutions that cover all the supply chain from production to warehouse management and distribution.

Figure 8 below depicts the nine blocks of the Osterwalder Canvas to describe the current business model of the System Integrators.

<table>
<tr><th>Key Partners</th><th>Key Activities</th><th>Value Proposition</th><th>Customer Relationship</th><th>Customer Segment</th></tr>
<tr><td rowspan="3">Long-term agreements are usually established to:<br>- Access vendor's knowledge and resources necessary to integrate and customise the vendor's product according to the customer needs.<br>- Offer the vendor's product at previously agreed conditions when proposing a new project to the customer.</td><td>- Business process reengineering,<br>- Deployment of ICT infrastructures and hardware,<br>- Installation and configuration of software packages,<br>- Customization of software packages,<br>- Ad-hoc development and Training,<br>- System monitoring and maintenance.</td><td rowspan="3">- Integration itself. For customers dealing with complex solutions implementation a perceived value is the integrator's capacity to deal with a variety of platforms and ICT standards.<br>- Ability to provide tailored solutions, including design, integration and ad-hoc development of systems according to the client's needs.</td><td>System integrators build long-term relationships with their customers. Typically each customer has a dedicated interface through account managers, both technical and administrative, who handle all details of the customer current and past contracts.</td><td rowspan="3">System Integrators normally operate on various markets segments. Regardless of their geographical reach, local, national or international, integrator firms tend to develop vertical offerings for different industrial sectors, e.g., manufacturing, retail, transport and logistics.</td></tr>
<tr><th>Key Resources</th><th>Channels</th></tr>
<tr><td>- Business analysts,<br>- Project managers,<br>- Technicians,<br>- Software developers,<br>- Infrastructure maintenance staff.</td><td>System Integrators typically sell directly through a dedicated sales force. Specialized sales channels are built for each main customer segment.</td></tr>
<tr><th colspan="2">Cost Structure</th><th colspan="3">Revenue Streams</th></tr>
<tr><td colspan="2">Human resources are the main voice in a system integrator's cost structure. Employees skills and expertise are central to the value proposition.<br>Most of the integrator's personnel are directly involved in customer projects; therefore these costs can be considered as variable costs, i.e., are directly related to the turnover produced by projects.</td><td colspan="3">The main income source for system integrators is effort spent on projects. Income is generated by charging the customer either for personnel time spent on a project or for achievement of certain project milestones agreed in the contract.</td></tr>
</table>

**Fig. 8** Current business model of ISI—system integrators

| Key Partners | Key Activities | Value Proposition | Customer Relationship | Customer Segment |
|---|---|---|---|---|
| The most important partners in a ICT vendor's network are:<br>- Resellers, i.e., distributors operating under specific reselling agreements.<br>- System integrators and consulting firms, supporting product implementation at user companies through activities such as installation, customization, integration and training.<br>- Complementary products vendors. These are products that complement or expand the product functionality, strengthening the vendor's value proposition. | - Product management (collection of users feedback, planning of updates),<br>- Research and development,<br>- Marketing and sales,<br>- Production (hardware).<br>- Packaging and distribution.<br>- Customer support.<br>**Key Resources**<br>- The product itself, in the form of patents, designs, source code, documentation and other artefacts belonging to the company.<br>- The customer base.<br>- The product image and company reputation.<br>- The human resources carrying out the above key activities. | -Product functionality, intended as the product's ability to "do the job", i.e., to meet the need by matching the user's expectations in terms of product features.<br>- Customer base. Buyers tend to pay great attention to the extension of the vendor's customer base, both as current number of users and as growth of the company market-share in time. | Vendors try to establish direct relationships with each customer, as the customer base represents a very important asset.<br>- With large customers a long-term relationship is established on company level.<br>- Relationships with SMEs are managed through standardized procedures, both on administrative and technical level.<br>**Channels**<br>- Direct sale through dedicated sales force.<br>- Indirect sale through resellers.<br>- On-line sale for simpler "off the shelf" products, i.e., products that can be acquired and implemented by the customer on its own.<br>- On-line sale for "service" products, i.e., products sold in the form of services like Software as a Service (SaaS) or more simply rental products. | Different market segmentation schemes are applied by each producer, depending on the features of the offered product and on other specific conditions such as the geographical reach of the company. Therefore, the only generally applicable segmentation of the market is the subdivision between large companies and SMEs. Typical elements of differentiation include:<br>- Functionality.<br>- Installation and rollout.<br>- Price, with dedicated price lists for SMEs.<br>- Accessibility, through dedicated sales and customer support channels for SMEs. |

| Cost Structure | Revenue Streams |
|---|---|
| Independent vendors have significant fixed costs. These include all costs for product management, research and development and customer support. Variable costs are generally less relevant for software vendors, including packaging, distribution and personnel directly involved in customer projects. Variable costs for production and acquired materials can be particularly relevant for hardware vendors. | The main income sources for independent vendors are:<br>- unit sales of licenses or hardware products;<br>- maintenance fees, paid on a subscription basis (typically yearly) for customer support and product updates.<br>Recently new business models have emerged, and in some cases have been successfully implemented (e.g., Salesforce.com ), based on provision of product functionality as a service. |

**Fig. 9** Current business model of ISI—software and hardware vendors

### 3.4.2 Software and Hardware Vendors

Software and hardware vendors provide ICT solutions for specific needs of broad categories of users, e.g., transport management software packages for LSC and LSPs or container tracking devices for various monitoring and security applications. In our analysis we refer to independent vendors, i.e., companies owning the products they sell. The product, either sold directly or through resellers, is the central element of a vendor's business. It represents the solution to a common need of a multitude of users. This solution, for the vendor to be successful, has to be of proven reliability and be updated over time through the users' feedback.

A typical vendor would approach the problem by equipping the product with interfaces complying with official or de-facto standards, popular in the sector of application. In this way user companies would be enabled to exchange information about logistic services with their business partners. There are many ICT solutions on the market, for instance, the ones provided by Oracle OTM, SAP, Ortec, Quintiq, and GT Nexus.

Figure 9 below depicts the nine blocks of the Osterwalder Canvas to describe the current business model of the Software and Hardware Vendors.

### 3.4.3 Connectivity Providers

Connectivity Providers are telecommunication companies providing basic connectivity services, e.g. via GSM, UMTS, wireless or satellite communication platform. Connectivity services are public, widespread (although availability and costs vary with location and roaming agreements) and generic, in that they are supporting various kinds of applications, for individuals and companies, including transport and logistics firms.

The communication infrastructure, which can be accessed through a variety of devices, is the central element of a provider's business. It is now common for such companies to try and differentiate their business by enabling advanced uses of the infrastructure. For example, many telecommunication companies now provide value-added services such as system hosting, client's infrastructure deployment and, in some cases, application provision in SaaS mode. Despite this differentiation strategy being relevant for the individual provider, it does not represent a business model innovation. When acting as integrators or application services providers, telecommunication companies simply adapt part of their structure to work as System Integrators or Vendors, with the same business models described in the previous chapters. Therefore, to our purposes we will concentrate on the core business of infrastructure provision.

As providers of the basic infrastructure, telecommunication companies are in an ideal position to offer higher-level connectivity services, such as data interchange or web-services platforms, to their many customers. There are already attempts to tackle this opportunity in the transport and logistics sector. For example, the Italian Government has been sponsoring the UIRNET initiative, aimed at connecting intermodal terminals and logistic operators through a shared platform and application software infrastructure. The national provider Telecom Italia has been appointed as provider of the connectivity infrastructure, including provision of devices and advanced integration services.

Figure 10 below depicts the nine blocks of the Osterwalder Canvas to describe the current business model of the Connectivity Providers.

| Key Partners | Key Activities | Value Proposition | Customer Relationship | Customer Segment |
|---|---|---|---|---|
| - Other Connectivity Providers with complementary infrastructures.<br>- Hardware and software vendors, to ensure compatibility with infrastructure standards. | - Infrastructure management and upgrade,<br>- Infrastructure monitoring and maintenance,<br>- Marketing,<br>- Customer support. | The main element in a connectivity provider's value proposition is the connectivity infrastructure itself, characterized by the following main features:<br>- Reliable and ubiquitous infrastructure.<br>- Affordable infrastructure, balancing the customer ability to pay and the provider competitiveness.<br>- Accessible infrastructure, i.e., facilitating users to connect both in technical and administrative terms. | Extremely high number of clients. "Personalized" relationships only with a limited number of large accounts, typically very large companies.<br>For all the other firms the relationship is managed through standardized procedures. | A first segmentation level applied by all Connectivity Providers is the subdivision between consumer and business markets.<br>- Consumer market: complex segmentation schemes, trying to capture specific user profiles (e.g., voice+SMS, voice+video, data intensive use). Then each profile can be targeted with a specific offer of services and tariffs tailored on the user's needs.<br>- Business market: specific offers dedicated to SMEs, also combining the basic connectivity services with "cloud" services such as system hosting and SaaS. |
| | **Key Resources** | | **Channels** | |
| | - The infrastructure itself.<br>- Financial resources to maintain and upgrade the infrastructure.<br>- Human resources for monitoring, maintenance and customer support. | | - Direct sale through dedicated sales force, only for large accounts.<br>- Local shops or resellers for small-medium clients. These are typically assisted through a network of own or affiliate services points distributed on the territory.<br>- On-line sales for small-medium clients. | |

| Cost Structure | Revenue Streams |
|---|---|
| Fixed costs are the main voice in a connectivity provider's cost structure. In particular, these include:<br>- Costs for maintaining, monitoring and updating the infrastructure.<br>- Personnel costs for customer service and support. | Revenues for Connectivity Providers are generated by service fees:<br>- Fixed fees, usually paid monthly, for subscription to the platform and for a bundle of basic services.<br>- Variable fees, increasing the fixed fee by an amount proportional to received service. |

**Fig. 10** Current business model of ISI—connectivity providers

## 4 Evolution of the Business Models

The proposed novel approach focuses on broadening and exploring the traditional concepts of business models showing their evolution when considering the future business environment.

At a conceptual level, a business model includes all aspects of a company's approach to developing a profitable offering and delivering it to its target customers. Research conducted in the last 10 years (Zott and Amit 2008), has established a link between business model innovation and value creation. This research points to the need for organizations to build a competency in business model innovation exploring possible business model alternatives.

Starting form this assumption, the goal of the analysis is to demonstrate how the introduction of business and ICT innovations in logistics modifies the current business scenario and market, by treating the business models as a variable and not a constant element. In this way we will be able to highlight the impact of ICT innovations in logistics not just as an enabler of operational improvements on the current business, but as a support infrastructure for new value proposition and new ways of cooperation in the logistics market.

### *4.1 Approach*

To this purpose, we explore the concept of a business model by addressing several core questions that the majority of business model researchers deal within their models:

- Who is the target customer?
- What need is met for the customer?
- What offering will we provide to address that need?
- How does the customer gain access to that offering?
- What role will our business play in providing the offering?
- How will our business earn a profit?

Usually, in a business model, the answers to these questions are fixed (Zott and Amit 2008). But what if they weren't? What if you considered each of them as a variable? What new opportunities could you capture that you can't address with your current business model? The answers to these questions form the essence of business model evolution.

We propose the following novel methodology to find out the evolution of the logistics market. The proposed approach is constituted of the steps described hereafter.

1. Collection of data about the current business models in the market

   We collected, as already presented din Sect. 3.1, the current business models implemented by the companies belonging to the LSC, FSI, LSP, and ISI categories, described as foreseen by the Osterwalder Canvas (Osterwalder et al. 2005).

2. Methodology to study and define the evolution of the business models

A template to examine the possible alternative answers to the questions above is proposed. The questions that help to shape a business model represent a series of decisions, each of which has a set of possible outcomes. The proposed template lays out various possible outcomes within the business model structure. Selecting one possibility from each category and then linking them together forms one potential new way to proceed. And, of course, selecting different combinations creates other possible outcomes. Working out what elements should be in a business model and then examining different combinations of them can be a rapid and robust way to explore the possibilities of business model innovation. This process has the potential, for instance, to uncover combinations that are common in other industries but not in your own.

The starting point of the template creation is the analysis of the impact and the effect of the introduced business and technical innovation on the value propositions of the different companies.

Therefore, in the proposed approach, we link the logistics innovations to the dimensions of the Canvas to find out the effect of these benefits on the business models and, in particular, how the elements that characterize the business models of each category of actors are influenced by these new solutions. For instance, by this matching, we can find out that a specific ICT technical innovation does not cause any changes in a dimension of the current business model, or it brings incremental changes into the current business model, or it offers a new opportunity for the business or even a disruption if the result of the impact is a solution that does not fit the company's current model.

Figure 11 below shows these relations and the impact of logistics innovations on the business models.

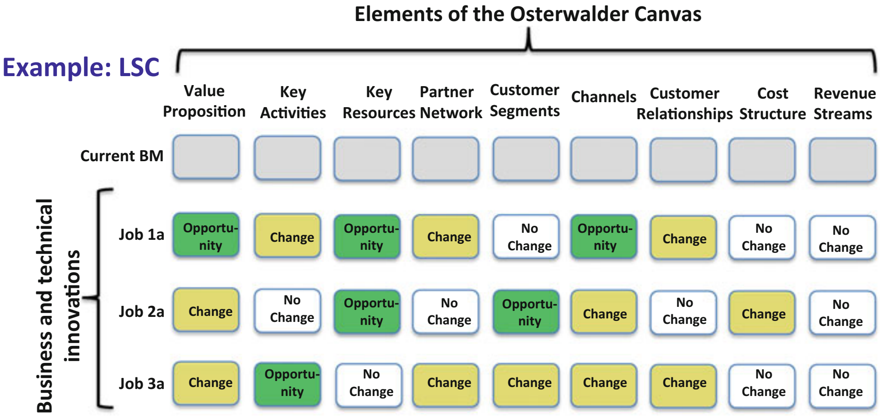


**Fig. 11** Proposed approach to analyze the impact of logistics innovations on the business models

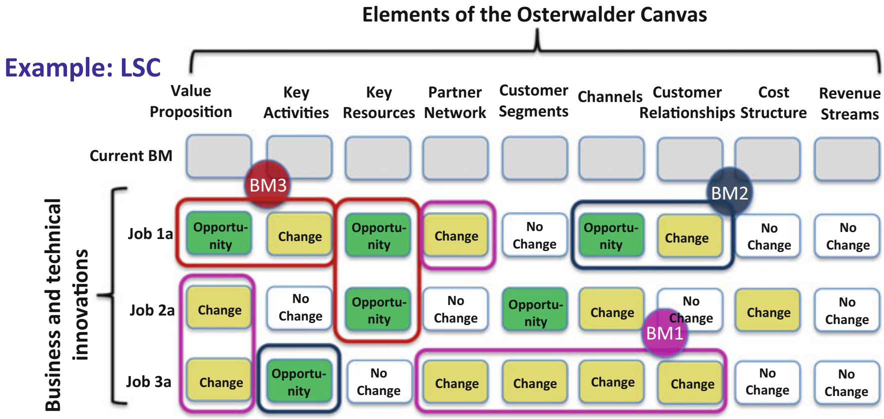


**Fig. 12** Proposed approach to analyze the evolution of the business models

This template is defined in different versions, one for each category of actors. The columns represent the nine elements of the Canvas and the rows are the logistics innovations that have a deeper impact for the considered category of actors.

The combination of the different effects on the current business models leads to the definition of new business models, for instance, based on the changes in the dimensions of the canvas or based on innovative solutions made possible and available to the market. Figure 12 below depicts an example of possible evolution of the current business model into different new business models, indicated as BM.

These choices are of course not infinite. In working through possible combinations of variables, it becomes clear that some are inherently interrelated.

What's more, there are likely only a handful of ways that any of these questions can be practically addressed while remaining consistent with the mission of the organization.

3. Evolution to new business models

By using this template is quite easy to understand the implications of different business models and make clearer, better-informed decisions about where and how they want to compete, and to identify the business models that will create the most value for customers. On the basis of these outputs, we are able to make assumptions on the evolution of the market of the different categories of logistics actors.

## 4.2 *Case Studies Examples of Business Model Innovations*

This Section presents two case studies in order to show how the proposed novel methodology is applied to study the evolution of logistics business models. The first case study concerns the evolution of the logistics roles presented in Sect. 3 in the context of a logistics business ecosystem. The analyzed business ecosystem refers to the iCargo Business Ecosystem, (iCargo Project 2012). While the second case study focuses on real and specific business models of logistics companies involved in the LogiCon project, (LogiCon project 2014).

### 4.2.1 Case Study 1: LSP-Shipper Cooperation on the Continent

The proposed case study aims to provide innovative continental door-to-door services to a potentially vast audience of manufacturing companies looking for greener but competitive supply chain solutions, by combining two key elements: (i) order/consignment reconstruction, to increase the load factor and synchronize transport and warehousing activities; (ii) real-time monitoring of emissions in road transport, to report carbon footprint and support supply chain planning decisions.

The case involves the LSC (Manufacturer) 3M, the FSI Deutsche Post DHL (DHL) and the ISI (Connectivity Provider) Marlo.

This case study belongs to the iCargo project framework (iCargo Project 2012) and at the basis of this approach reside the ability for the company involved to integrate their planning and execution processes through the iCargo ecosystem.

There are two core capabilities to be developed in this case:

- A new logistics service for order/consignment reconstruction,
- Capabilities for real-time monitoring of emissions in road transport.

These two elements are combined to provide innovative door-to-door services to a potentially vast audience of manufacturing companies looking for greener but competitive supply chain solutions. Order/consignment reconstruction aims at increasing the load factor and synchronizing transport and warehousing activities. Through real-time monitoring, the impact of such actions can be not only reported, but also assessed to support supply chain planning decisions.

The current business models of the actors involved in the proposed case study have already been presented in Chapter "Future-proofing supply chains". Next, we have applied the proposed methodology to find out how their business models will evolve inside a new logistics business ecosystem consisting of (i) business communities sharing a common framework, and (ii) a semantic enhanced ICT infrastructure supporting interoperability and cooperation between software services, company systems and intelligent objects. These two elements enable profiling, search, combination and use of logistic services to provide complete door-to-door solutions.

Applying the proposed approach, we have studied the evolution of the business models of the actors involved in the case study and hereafter we detail the results. The presented business models are compared to the current ones, already described in Sect. 3. Details are provided in Figs. 13, 14, and 15 and only the dimensions of the business model Canvas that represent an evolution from the current status are described.

<table>
<tr><th>Key Partners</th><th>Key Activities</th><th colspan="2">Value Propositions</th><th>Customer Relationships</th><th>Customer Segments</th></tr>
<tr><td rowspan="3">No changes</td><td>Opportunities:<br>- environmental conscious management and organization of the entire logistic chain;<br>- environmental monitoring of the logistic chain.</td><td colspan="2" rowspan="3">New opportunity: certified low emission in the Supply Chain</td><td>No changes</td><td rowspan="3">Opportunity: new customers interested in sustainable logistics</td></tr>
<tr><th>Key Resources</th><th>Channels</th></tr>
<tr><td>No changes</td><td>No changes</td></tr>
<tr><th colspan="3">Cost Structure</th><th colspan="3">Revenue Streams</th></tr>
<tr><td colspan="3">No changes</td><td colspan="3">No changes</td></tr>
</table>

**Fig. 13** Business model of LSC environment-focused manufacturer

<table>
<tr><th>Key Partners</th><th>Key Activities</th><th colspan="2">Value Propositions</th><th>Customer Relationships</th><th>Customer Segments</th></tr>
<tr><td rowspan="3">No changes</td><td>Opportunities:<br>- define, introduce and manage a set of processes and information to calculate the global environmental performances of the services;<br>- specialization in high-value activities exploiting monitoring capabilities, e.g., certification, reliability, quality, cargo safety.</td><td colspan="2" rowspan="3">New opportunity: offer door-to-door logistics solutions based on specific know-how and on dynamic planning and monitoring capabilities</td><td>No changes</td><td rowspan="3">No changes</td></tr>
<tr><th>Key Resources</th><th>Channels</th></tr>
<tr><td>Opportunity: cooperation with new partners dynamically also on short-term agreement through the new ecosystem</td><td>Opportunity: new sales channels through the new ecosystem</td></tr>
<tr><th colspan="3">Cost Structure</th><th colspan="3">Revenue Streams</th></tr>
<tr><td colspan="3">No changes</td><td colspan="3">No changes</td></tr>
</table>

**Fig. 14** Business model of virtual integrator

The new business model of the 3M company is related to its new role of environment-focused manufacturer, see Fig. 13. The main changes in the business model concern:

- *Value Proposition*, that will be affected by the possibility to offer certified low-emissions supply chains;
- *Key Activities and Key Resources* that will change correspondingly, exploiting iCargo for management and monitoring the entire logistic chain to enhance the environmental performances.
- *Customer Segments* will be extended to include customers interested in sustainable products.

<table>
<tr><th>Key Partners</th><th>Key Activities</th><th>Value Propositions</th><th>Customer Relationships</th><th>Customer Segments</th></tr>
<tr><td rowspan="3">No changes</td><td>Opportunities:<br>- business connectivity services management and upgrade;<br>- connectivity infrastructure monitoring and maintenance;<br>- marketing;<br>- customer support</td><td rowspan="3">New opportunity: business-level connectivity for logistics information services</td><td>No changes</td><td rowspan="3">No changes</td></tr>
<tr><th>Key Resources</th><th>Channels</th></tr>
<tr><td>Opportunities:<br>- business connectivity technology;<br>- knowledge on business interoperability standards and logistics processes;<br>- human resources for monitoring, maintenance and customer support</td><td>No changes</td></tr>
</table>

<table>
<tr><th>Cost Structure</th><th>Revenue Streams</th></tr>
<tr><td>No changes</td><td>Opportunities:<br>- fixed subscription fee;<br>- variable fees, e.g., by volume of data exchanged</td></tr>
</table>

**Fig. 15** Business model of connectivity infrastructure provider

The DHL business model evolves towards its new role of Virtual Integrator. DHL is also a new service provider able to exploit the richer information environment offered by the iCargo ecosystem to provide value-added integration services, such as, e.g., certified low-emissions shipments or cargo safety control throughout the supply chain. Their value proposition will combine the iCargo dynamic planning and monitoring capabilities with the know-how built by the integrator in specific areas such as supply chain carbon footprint and international trade management. The main changes in the business model represent opportunities for new business, see also Fig. 14:

- *Value Proposition* will be the ability to provide more effective, low-cost and low emissions door-to-door logistic chains, made possible by the iCargo capabilities to compose, plan and monitor such chains.
- *Key activities* will be the ones making use of iCargo information to provide high-value services, such as environmental performances optimization, certification, cargo monitoring and safety management.
- *Channels* will not be the traditional ones, but sales will be generated through the iCargo ecosystem itself. Here the Virtual Integrator might be visible as a traditional service company taking care of requests coming from the LSC or, in its more advanced form, might be a software agent acting transparently to assist the LSC in composing the integrated solution on its own.

The Marlo business model as a new Connectivity Infrastructure Provider is characterized by the following main innovations, compared to basic infrastructure providers, see also Fig. 15:

- *Value Proposition* consists in business-level connectivity for the various types of iCargo stakeholders like, LSC, FSI, LSPs and Information Services Integrators. This means enabling the users to expose, integrate and use logistic information services by connecting existing systems.

- *Key Activities* are providing, managing and upgrading the iCargo ecosystem ICT infrastructure, monitoring the infrastructure operation and supporting users in accessing and making use of the infrastructure.
- *Key Resources* include the iCargo ecosystem infrastructure technological components, knowledge on interoperability standards and logistics to support the users, and skilled human resources to carry out the above activities.
- *Revenue Streams* will consist of service fees, calculated according to the two main policies currently applied by basic connectivity providers:
  - fixed fees, e.g., a monthly amount for having access to the infrastructure and being able to publish own services and access other users' services,
  - variable fees calculated on the amount of activity carried out by the users, e.g., number of transactions or volume of data exchanged through the iCargo infrastructure. The modulation of such fees is particularly important to favor or disfavor participation of user companies to the ecosystem, leading to different pricing strategies by size and type of company. For example, an aggressive policy to attract SMEs would be to propose a very low fixed fee, ideally zero, and a very high threshold for application of variable fees, e.g., by including a relatively high number of transactions in the fixed fee. Conversely, large company and services providers like FSI and ISI might be charged in proportion of the business carried out through the ecosystem, by applying a pricing model based essentially on variable fees.

As a conclusion, we can state that the involved actors will evolve in the following terms:

- the LSC (3M) will see no disruption of its current business model, since there is the opportunity to enhance the business through by becoming environment-focused manufacturer;
- the FSI (DHL) will re-focus its value proposition on its core services rather than on the integration. DHL will cover the role of Virtual Integrators as provider of pure information services and competencies for better composing, planning and monitoring logistic chains.
- the ISI (Marlo) will focus on the interoperability on the business level, being a Connectivity and Monitoring Infrastructure Provider, offering logistics monitoring as a combination of hardware/infrastructure rental and services.

### 4.2.2 Case Study 2: Multi-sided Platform for Controlled Data Sharing and Innovative Logistics Apps

It is widely considered that the success of the logistics cluster not only relies on having a good physical infrastructure. Having an information infrastructure to support business collaboration is also considered very important. For instance, if it is very easy for organizations to share data with business partners in a controlled way, this can lower the barriers for setting-up collaboration.

This case study belongs to the LogiCon project framework (LogiCon Project 2014) and focuses on the creation of an ecosystem in which stakeholders like shippers, consignees and LSPs operate as data providers and consumers with the objective to optimize capacity utilization, reduce waiting times, increase market share, etc.

The ecosystem consists of a Multi-Sided Platform (MSP) for controlled data sharing and innovative apps developed by web entrepreneurs for the Port of Twente community.

The case involves the LSP (Combi Terminal Twente, CTT) and one ISI (NexusZ). The LSP is a terminal operator providing transshipment services at their terminals and logistic services between Rotterdam and Twente terminals. They are a user of the apps and smart data services built on the information platform. They are also a provider of data to the platform, to be shared with others in the business community. While, NexusZ is a web entrepreneur providing their Exomodal solution for (i) smart data services and (web-) apps to logistic actors and (ii) tools for logistic actors to integrate and share data.

In this scenario, logistic stakeholders are able to share data by directly interfacing with the platform, but also by utilizing innovative apps. The MSP enables direct interaction between the multiple customer types affiliated to it. This particular approach of MSP implies all types of interactions between all stakeholders in their different roles, e.g. between shippers and LSPs and LSPs and carriers. The MSP is not equal to an intermediate or re-seller which take control of interactions; the MSP enables those interactions between multiple customers groups.

The current business models of the actors involved in the proposed case study have already presented in chapter "Future-proofing supply chains". Also in this case, we applied the proposed methodology to find out how their business models will evolve towards a sustainable business model for the multi-sided platform in the Port of Twente community. This business model heavily depends on:

- a business case for each use case running on the platform supporting a specific objective (increased capacity utilization, reduced waiting time, etc.);
- a business model for a web entrepreneur in providing functionality to logistics stakeholders by offering for instance an innovative app. This business model can depend on the business case of one use case, but also reflects the business strategy and model of the web entrepreneur.

Similarly to the other case study, by applying the proposed approach, we have studied the evolution of the business models of the actors involved in this case study and hereafter we detail the results. The presented business models are compared to the current ones, already described in Sect. 3.

The new business model of the CTT company is related to its new role Value-added Service Providers. These providers will exploit new logistic services with additional value-added elements, made possible by the information services available in the ecosystem, see Fig. 16. In particular:

| Key Partners | Key Activities | Value Proposition | Customer Relationship | Customer Segment |
|---|---|---|---|---|
| App developers<br>Large enterprises as customers of SMEs<br>TLN, Port of Twente | Provided back office connections for sharing data in the paperless transport format with SMEs | Paperless transport | SMEs: via their customers (shippers, LSPs, large carriers) | SME Road Carriers |
| | **Key Resources** | | **Channels** | |
| | WSO 2 API Manager<br>Hardware<br>Human resources, offices | | IT solution providers developing apps<br>Other interested IT solution providers, e.g., providing On Board Units (OBUs) | |

| Cost Structure | Revenue Streams |
|---|---|
| Operational costs<br>Development costs | Pay-per-transaction roaming the model off app providers (initial entry free) |

**Fig. 16** Business model of LSP value-added service provider

- *Value Proposition* will still be based on fulfillment of the main customer needs (e.g., transport, warehousing) but at the same time it will include innovative solutions aiming, for instance:
  – to repack, label and perform other customer-specific operations, up to final assembly, as close as possible to the customer, reducing uncertainty and variability along the supply chain;
  – to cross-dock and combine incoming cargo from different sources into a single shipment, reducing inventory levels along the chain and increasing the load factor of the involved vehicles;
  – to operate last mile deliveries on behalf of the supplier, managing customer orders, inventory replenishment as well as transport planning according to Service Level Agreements.
- *Key Activities* will include a number of specific tasks depending on the type of service offered, but in all cases a high level of synchronization will be required with the activities of upstream and downstream LSPs, and with the overall door-to-door plan.
- *Customer Segments* will be affected in that, by offering new value-added services, LSPs will have the opportunity to widen their market by addressing different transport and logistics needs of their current customers, and to attract customers in different segments as well.

The ISI, NexusZ as a web entrepreneur, evolves towards the Functionality as a Service, FaaS, business model that is characterized by the following main innovations, see also Fig. 17:

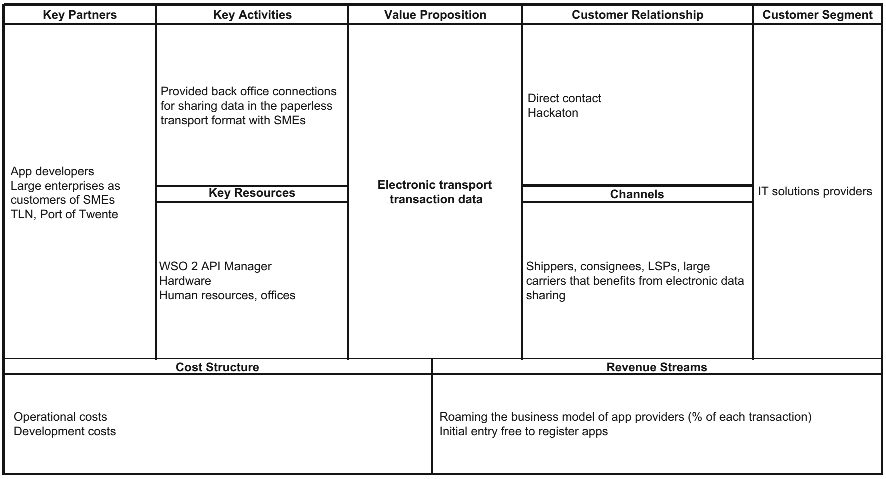


**Fig. 17** Business model of FaaS

- *Value Proposition* is not essentially changed, as its main elements are the functionality and acceptance by the customer base, but for the customer it will mean accessing the functionality rather than owning the product providing it.
- *Key Activities* are the same as for traditional vendors, apart from product-related activities like packaging and distribution that are no longer needed.
- *Partner Network* is substantially changed. Rather than building partnerships with system integrators and complementary products developers, FaaS providers will work primarily with:
  - Connectivity providers, to deliver their functionality through the iCargo ecosystem infrastructure;
  - Complementary services providers, to seamlessly integrate different functionalities in iCargo processes. For example, a provider's planning service will be able to operate on data from a carbon footprint evaluation services from a different provider.
- *Channels* will consist essentially of on-line sales.
- *Customer Relationships* will be maintained through standardized procedures, supported by web-based tools.
- *Cost Structure* will be similar to current vendors' structure, only consisting of fixed costs.
- *Revenue Streams* will consist of service fees. Two main categories of fees can be applied, even in combination:
  - Subscription fees, i.e., a fixed amount paid for accessing the functionality over a certain period of time, e.g., on a monthly basis;
  - Pay-per-use fees, i.e., a variable amount calculated on the volume of activities carried out by the user, e.g., number of shipments planned using the provider's functionality.

As a conclusion, we can state that the involved actors will evolve in the following terms:

- the LSP (CTT) will not see a real disruption of its current business model, since it will exploit new logistic services with additional value-added elements;
- the ISI (NexusZ), covering a Functionality as a Service role, will focus on the utilization of its technology and know-how to perform planning and monitoring tasks on behalf of the clients.

The main results of the presented work deal with the study of the evolution of the business models of the main category of actors involved in a logistics services value chain, where innovations are supported by advanced ICT solutions.

The innovation of the proposed approach is related to the exploration of the business model concept as an evolution and not only as a static analysis, in order to capture systematically new opportunities that cannot be perceived by looking at the business as it is.

By analyzing the value creation and business logic of companies, through a specifically designed business model framework, it is possible to develop a solid understanding about the principles and dynamics of a specific industry. The business model also highlights the critical service related issues like relationships with customers needing special attention in the industry's development, and it can be utilized in designing new services, too.

On the basis of the presented results the following assumptions can be derived:

- in the market of LSC (Manufacturers) an increasing number of companies will introduce ICT-based innovations to modify their logistic operations and the offered services, to meet the demand for environment-friendly products and supply chains;
- the size of the market of traditional asset-bound forwarders will decrease because of the gradual disappearance of physical intermediaries and a new kind of integrator will emerge, specialized in providing integrated door-to-door solutions to the clients. These Virtual Integrators will make use of ICT to provide a "neutral" integration service, leveraging specialized competences and information assets. The Virtual Integrators might evolve either from former forwarders or from information services providers who have developed enough competences to provide complete logistic solutions instead of simple IT functionality;
- the market of LSPs will not be significantly modified, but rather by other factors and general market trends. In particular, a large part of LSPs will modify their business models by exploiting the ICT capabilities to provide value-added services of more strategic nature for the LSC like, e.g., advanced forms of cross-docking and postponement of various logistics and assembly operations;
- the size of the market of Information Services Integrators will grow significantly. The traditional system integrator business model will face a disruption: the business of selling interoperability projects and platforms will shrink, from the current not-too-relevant size to a very marginal portion of the overall ICT market. Business-level connectivity will emerge as a new important market,

actually providing the interoperability of systems and processes between logistic actors. This will be the main competitor of the current system-integrator business model, and the origin of its disruption. "Functionality as a Service" will be the predominant form of access to logistic data and services. In this model, users will not just rent the software and access it remotely, but will be able to engage providers on the spot, paying for the actual functionality they make use of. Finally a new kind of provider will emerge to provide integrated door-to-door solutions to the clients. These Virtual Integrators will actually compete with traditional freight forwarders, which can also evolve to this type of business model.

Finally, the proposed approach could be also generalized to other applications and various domains, such as urban freight transport, in which the key issues concern the investigation of the value creations and the effect of innovative strategies on the current business models.

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## References

Accenture (2012) Achieving high performance in Freight Forwarding & Contract Logistics

Amit R, Zott C (2001) Value creation in e-Business. Strateg Manag J 22:493–520

Anderson C (2008) The long tail. Hyperion Books, New York, NY

Barratt M (2004) Understanding the meaning of collaboration in the supply chain. Supply Chain Manag 9(1):30–42

Bask AH, Tinnila M, Rajahonka M (2010) Matching service strategies, business models and modular business processes. Bus Process Manag J 16(1):153–180

Chapman RL, Soosay C, Kandampally J (2002) Innovation in logistic services and the new business model: a conceptual framework. Manag Serv Qual 12(6):358–371

Chesbrough H (2007) Why companies should have open business models. Sloan Manag Rev 48(2):22–28

Christensen C, Johnson M, Kagermann H (2008) Reinventing your business model. Harv Bus Rev 86(12):50–59

CVIS Cooperative Vehicle-Infrastructure Systems. http://www.cvisproject.org/

Delfmann W, Albers S, Gehring M (2002) The impact of electronic commerce on logistics service providers. Int J Distrib Logist Manag 32(2):203–222

DiSCwise project (2011) http://www.discwise.eu

Dyer JH, Cho DS, Chu WJ (1998) Strategic suppliers segmentation: the next best practice in supply chain management. Calif Manag Rev 40(2):57–77

Epatko E (1994) Suppliers can help meet customers' desires. Purchasing 117(8):9–11

Ernst & Young (1999) International market assessment: the new manufacturing company. In: Smith A (ed) Australian ingenuity, manufacturing for the world. Focus Publishing, Newburyport, MA

Euridice Project (2008) EURopean Inter-Disciplinary research on Intelligent Cargo for Efficient, safe and environment-friendly logistics. http://www.euridice-project.eu/

Freilot Project (2009) http://www.ecomove-project.eu/links/freilot/

Håkegård JE, Holter B, Tardy I, Moen T (2011) Assessment of wireless technologies. Deliverable 4.4 of the Smartfreight project
Hamel G, Prahalad CK (1989) Strategic intent. Harv Bus Rev 67(3):63–74
Helo P, Szekely B (2005) Logistics information systems: an analysis of software solutions for supply chain co-ordination. Ind Manag Data Syst 105(1):5–18
iCargo Project (2012) iCargo Deliverable D1.3—iCargo Vision
Integrity Project (2009) http://www.integrity-supplychain.eu
Lambert DM, Cooper MC (2000) Issues in supply chain management. Ind Mark Manag 29:65–83
Linder J, Cantrell S (2008) Carved in water: changing business models fluidly, a working paper from the Accenture Institute for Strategic Change. http://www.accenture.com/Global/Research_and_Insights/Institute_For_High_Performance_Business/By_Subject/ Strategy/CarvedInWater.htm
LogiCon project (2014) Description of work
Magretta J (2002) Why business models matter. Harv Bus Rev 80:86–92
Markides C, Charitou CD (2004) Competing with dual business models: a contingency approach. Acad Manag Exec 18:22–36
Mason R, Lalwani C, Boughton R (2007) Combining vertical and horizontal collaboration for transport optimisation. Supply Chain Manag Int J 12(3):187–199
Osterwalder A (2004) The business model ontology. A proposition in a design science approach. University of Lausanne, Dissertation. http://www.hec.unil.ch/aosterwa/PhD/
Osterwalder A, Pigneur Y, Tucci CL (2005) Clarifying business models: origins, present, and future of the concept. Commun Assoc Inf Syst 15:1–25
Pateli A, Giaglis G (2003) A framework for understanding and analysing e-business models. Bled Electronic Commerce Conference
Porter ME (1980) Competitive strategy: techniques for analysing industries and competitors. The Free Press, New York, NY
Rousseau F, Montaville F, Videlaine F (2012) Challenges and winning models in logistics. Bain & Company. http://www.bain.com/publications/articles/challenges-and-winning-models-in-logistics.aspx
Schilling MA, Hill CWL (1998) Managing the new product development process: strategic imperatives. Acad Manag Exec 12(3):67–81
Shafer SM, Smith HJ, Linder JC (2005) The power of business models. Bus Horiz 48(3):199–207
Shin H, Collier DA, Wilson DD (2000) Supply management orientation and supply/buyer performance. Mid-Am J Bus 15(2):11–20
Seddon PB, Lewis GP, Freeman P, Shanks G (2004) The case for viewing business models as abstractions of strategy. Commun Assoc Inf Syst 13:427–442
Sinfield JV, Calder E, McConnell B, Colson S (2011) How to identify new business models. Manag Rev 28(10):18–22
Smartfreight Project (2008) http://www.smartfreight.info
Stahler P (2002) Business models as a unit of analysis for strategizing. In: Proceedings of the 1st International workshop on business models, Lausanne, Switzerland. http://www.business-model-innovation.com/english/definitions.html
Teece D (2010) Business models, business strategy and innovation. Long Range Plan 43:172–194
van der Sterre PJ (2011) EVO's Logistics yearbook edition 2011. ISBN: 978-90-79470-00-6
Verwijmeren M (2004) Software component architecture in supply chain management. Comput Ind 53(2):165–178
Vonderembse MA, Tracey M (1999) The impact of supplier selection criteria and supplier involvement on manufacturing performance. J Supply Chain Manag 35(3):33–39
Zott C, Amit R (2008) The fit between product market strategy and business model–implications for firm performance. Strateg Manag J 29(1):1–26

# Future-Proofing Supply Chains

**Alex Van Breedam**

**Abstract** Due to the rapidly changing environment and the changing customer behaviour, companies will have to rethink the way they deliver their products and services. Most companies are still operating a supply chain that was designed in times of cheap oil, before any trace of e-commerce. These supply chains now run up against their limits and they will definitely not stand the upcoming challenges of tomorrow, the biggest of which are probably societal and environmental. Twenty challenges are identified and their impact on supply chains is described. In order to be successful in a rapidly changing environment, companies have a strong interest to make their supply chains future-proof at all times. A future-proofing diagnosis is developed to assess the supply chain of a company and to evaluate the gap with the upcoming societal, consumer and logistics challenges. Companies who are future-proofing their supply chain will identify and seize much faster the supply chain opportunities to create a competitive advantage.

## 1 Introduction

Supply chains are operating in a rapidly changing global environment. Not only societal changes, but also changes in the way consumers behave, have or might have a direct impact on logistics. Consequently, the logistics environment is changing and will continue to change accordingly. This has a direct impact on supply chains of companies. If a company's supply chain cost and carbon footprint is increasing, while service level is continuously decreasing because of increased inventories, longer waiting times, badly aligned production processes, decreasing service levels, etc... then this could be interpreted as a sign that the current supply chain strategy might not be adequate anymore to the environment it is operating in.

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At first, it is important to try to understand how the environment in which supply chains operate is currently changing and how it will evolve in the future. Based on the expected changes and future challenges, a company needs to deploy a strong, but adapted supply chain strategy. Fundamental to a strong supply chain strategy is integration. The strength of a supply chain heavily depends on the internal integration among the subsequent supply chain departments procurement, production and distribution on the one hand and on the external integration with suppliers and customers on the other hand. Information availability, preferably as real-time as possible, and communication, i.e. the so-called supply chain visibility, is mandatory to pursue a strong integration.

Today, a lot of companies are still in the process of creating more supply chain visibility, internally and externally. Supply chain visibility is a key success factor for the customer-dominated and pull-oriented environment in which supply chain are currently operating. With the expected increase of the customer domination in the very near future, strongly boosted by the fast growing e-commerce, the real-time granularity should increase even more. An unwanted consequence is an expected acceleration of the demand for capacity. It is clear that society will not be able to swallow an unlimited capacity increase. Therefore, trend watchers are already announcing that we are approaching the tilting point of this “on-demand” customer dominance. As a result, the shift towards managing scarcity in a more fair society is starting slowly. This would impose other requirements to supply chains, including capabilities of sharing and pooling capacity, with a focus on more circular cradle-to-cradle concepts and reverse logistics.

Companies need a strong framework to assess their supply chain in the perspective of future trends and challenges. The aim thereof should be the clear identification of the gaps to bridge towards a future-proof supply chain. Such a diagnosis tool should be easy to use, maintain and understand. Ultimately, the diagnosis tool should be used to compare and benchmark companies with respect to their supply chain readiness for future challenges.

We developed the *Future-Proofing Supply Chain Diagnosis* framework as an integrated approach to diagnose supply chains in view of twenty future challenges with a substantial impact on logistics and supply chain management. This *Future-Proofing Supply Chain Diagnosis* framework is presented in this article. In the first part of this article, the twenty challenges are described and classified into three categories: changes in environment, changes in customer behaviour and changes in logistics. Next, a vision on the evolution of supply chains is developed. Subsequently, an insight in the methodological approach of the Future-Proofing Supply Chain Diagnosis is proposed. The main observations of the first pilots are reported and finally some conclusive remarks are formulated.

## 2 Changing Environment

The global environment in which companies are acting is changing and will continue to change even more substantially. Far and foremost, demography will change dramatically: the world population will grow from seven billion to nine billion in 2050 (United Nations 2013). The shift of the economic power and the development of emerging countries will give more people access to welfare. This will definitely require a performance increase of the current logistics systems, that should also be able to expand rapidly to new areas. Hence, logistics systems should be capable of absorbing substantial increase in freight volumes without a proportional increase in environmental impact. Companies should be able to roll out stable distribution systems, even from scratch, in emerging and developing regions in a fast but sustainable and lasting way. Also should the supply chain be capable of absorbing adequately substantial increases in volume.

In the meantime, urbanization is expected to increase from 54 % today to 66 % or more towards 2050 in the developed countries (United Nations 2014). It goes without saying that the increased urbanization means a real challenge for logistics, especially if e-commerce and home deliveries will continue to boost. Inversely, the consolidation potential that might result from a high degree of urbanization could be considered as an opportunity for logistics. Nevertheless, the physical accessibility of the customer will continue to deteriorate with the higher urbanization. As a result, the last mile cost will increase accordingly (Sullivan Research Service 2013). New stable and sustainable distribution channels and structures will have to be developed to guarantee reasonable lead times to the customer at a feasible supply chain cost.

The ongoing globalization, free trade and harmonization of legislation have been helpful for companies to make their supply chains more efficient, for instance through the geographical relocation of production. However, the rush to Asia was often driven by pure cost-cutting strategy, without considering the often negative impact on customer service. Moreover, from a total cost of ownership perspective, the long-term outcomes of off-shoring on supply chain responsiveness are most often negative, as observed by Stank et al. (2014). The total cost of ownership is a full cost accounting approach in which hidden costs, including cost of lead time, inflexibility, quality, lost sales, etc..., are made visible.

As a counterbalance to globalization, a lot of companies embrace the glocalization concept by thinking globally and acting locally and thus adapting their global products and services to the local market and cultures.

More globalization and free trade is often counterweighted by an increase of the regulatory pressure. This is particularly the case for some logistics top-regions in Western Europe. Clearly, this might hinder the further growth of logistic infrastructures. Hence, government and companies will be obliged to focus more on innovative concepts to better utilize the existing infrastructure instead of building new ones.

As a result of the globalization and the glocalisation, supply chains have become longer and more complex (Ballou 2004). In many cases, however, the risk exposure of companies has increased accordingly (Grandjot 2006). In general, supply chain risks could be demand side (e.g. demand volatility, forecast inaccuracy), supply side (e.g. supplier and supply problems), process (e.g. machine breakdown), control (e.g. controlling mechanisms), relationship (e.g. opportunistic behaviour or leakages to competitors), environmental (e.g. socio-economic, political and legal), logistical (e.g. congestion) and catastrophic risks. The objective of Supply Chain Risk Management is for companies to understand what the effect is of each risk source on the supply chain risk exposure. Besides the substantial impact of supply and demand side risks, the catastrophic risks have showed to have a dramatic impact on supply chain performance (Sharma and Bhat 2014). Although surveys have demonstrated that most risks sources are inside the company (Jaberidoost et al. 2013), some events have shown how risks beyond the control of individual organizations can have consequences that cannot be mitigated by one organization alone. These events could include natural disasters, extreme weather, conflict and political unrest, terrorism, import/export restrictions and sudden demand shocks (World Economic Forum 2012). The disruptive impact of these possible risks on supply chains and transportation should force companies to asses and review their risk management procedures at the board level (Hendricks and Singhal 2005). Moreover, appropriate management of risks beyond the control of the individual company will require governments to take up their role through public-private partnerships.

Developed countries in the Western world will probably have to face a stagnation or even a drop of their wealth. Overall this could lead to a status quo of the handled flows of goods. However, given the evolution towards decreasing drop sizes and increased delivery frequencies, the capacity requirements will continue to grow. This will increase the pressure on the price of transport services. If, by that time, more intelligent and sustainable logistics solutions for better capacity utilization will not have been institutionalized, the logistics sector will suffer even more than today. Nevertheless, the logistics sector should start to explore and invest in new market and areas, as there are energy and water or humanitarian logistics (Von der Gracht and Darkow 2013).

Societal pressure, such as the demand for more environmentally-friendly products will force companies to rethink their supply chain accordingly (Finisterra Do Paço et al. 2009). It is clear that future supply chains will have to focus more on environmental concerns (Soni and Kodali 2008) and reduce $CO_2$-emissions and energy consumption (Piecyk and McKinnon 2010; GCI and Capgemini 2008). The World Economic Forum (2015) identified supply chains and the safe supply of energy as key factors that will fundamentally shape the world's future and are "central to the functioning of the world economy and to the well-being of global society". Consequently, future supply chains, especially regarding the long-term future, will not only have to be designed to minimize cost and maximize service level; environmental sustainability will be become equally important (GCI and Capgemini 2008). Therefore, companies should start to implement an Environmental Management System to track and manage environmental performance and to track performance against regulatory requirements (Handfield et al. 2005). Corporate social responsibility has to evolve towards corporate social value creation. Supply chain improvements should be cost saving and beneficial for society at a time.

Finally, new types of economy are emerging. Three distinctive types might have an important impact on the supply chain: the sharing, the servitization and the circular economy. The sharing or collaborative economy is based on sharing resources to co-create, co-produce and co-distribute goods and services. Sharing supply chain capacity, e.g. shared manufacturing platforms, shared warehousing or transportation co-loading, is rapidly gaining ground in various industries. While a vast number of strong horizontal collaborations in logistics have already been reported (see $CO^3$-Project 2014), supply chain collaboration is still not widely institutionalized so far. Mental thresholds, proper to pooling and sharing of capacity, still appear to be obstructing for a number of companies. External incentives, like a carbon tax or structural traffic pricing, could be instrumental in pushing companies towards more supply chain pooling and sharing.

Servitization is a total concept for manufacturers to offer services tightly coupled to their products. It's about moving from a transactional (just sell a product) to a relationship-based business model (delivering a capability) featuring long-term, incentivized, 'pay-as-you-go' contracts. Hence, supply chains should be focussed more on offering appropriate services to the customer throughout the lifecycle of the product than just delivering the product to its first-time buyer. Many manufacturers started this long before, say for examples Rolls-Royce offering Total Care on gas turbines for their airline customers based on a 'fixed dollar per flying hour'; Xerox delivering 'pay-per-click' scanning, copying and printing of documents etc. (Baines et al. 2009; Baines 2013).

Along with this, the circular economy will make business to rethink the entire process beyond today's linear approach. So there will be a shift from linear to circular where recycling is boosted and the loss of valuable materials is prevented. Many big firms already predicted this evolution and started to inject these strategic changes into their core business model, which shows that they are preparing themselves for the circular economy (World Economic Forum 2014).

## 3 Changing Consumer Behaviour

As opposed to the more medium and long term perspective of the changing environment, the change in consumer behaviour, which is going on nowadays, might have an immediate impact on supply chains and logistic activities. The switch from the one-channel "brick and mortar" to an omni-channel buying behaviour of the consumer is already affecting a lot of companies today. While e-commerce, social networks and mobile channels were a nice to have until a few years ago, they have become a must-have today. The complexity of many companies' supply chain structures has more than proportionally increased since e-commerce and mobile sales were added to the current distribution structures. The challenge for most companies remains the supply chain integration of the different distribution channels (Tetteh and Qi 2014). On top of that, the internet sales have forced companies to adapt the speed and the performance of their ICT systems and tools (Lasserre 2004).

The e-commerce explosion has emphasized even more the consumer dominance in the supply chain, especially with regard to service level and lead times. Where "next day delivery" has become the rule, the big e-tailers have already started experimenting with the "next hour delivery", however today still focussed on fresh products. And with this all and against all logic, transport is most often offered for free with internet purchases. How could you make the consumer aware of the value of transport if his parcel—with a price often inferior to that of the transport itself—is delivered at no cost? Apparently, e-tailers have made customer used to free transportation, while it is known that transport generates a lot of external costs to society. On top of this, some dominating e-commerce companies are even offering a free return, in order to realize an accelerated market penetration of e-commerce sales. This is particularly true for products that customers like to sense or try out before buying. The expected accelerated growth of internet sales in combination with the increased urbanization could become a real challenge for logistics, especially in relation to environmental issues and viability of cities.

The customer's dominance in the supply chain appears also in the business-to-business segment, where suppliers are pushed to decrease their lead times and to supply smaller quantities more frequently within ever narrowing delivery-windows. As a result, logistic activities come more and more under pressure and additional capacity might be required, because existing capacity could be unsufficient.

In the long run, it is almost certain that the 3D printing will have its effect on the consumer behaviour. By adopting this technology at home, the consumer becomes producer. Consequently, the buying profile of the consumer will evolve from finished products to print supplies, considered that he would be able to 3D print most of his needs and products. Advantageously, this might result in lead time relaxation for logistics. More generally, future supply chains should be supportive to new product innovation. Due to the continuously decreasing life-cycle of most products in combination with the increasing number of product innovations, the time-to-market for new products should be short. Hence, an agile supply chain is critical for a fast launch of new products to the market.

Finally, the speed of change in ICT technology remains an important enabler of supply chain management. Performing supply chains require excellent ICT. The faster the information flow of the supply chain, the more reactive and adaptive the flow of goods will be. The evolution of ICT technology shall be supportive to supply chain management, mainly at two levels: planning and monitoring. Supply chain planning requires powerful calculation and optimisation tools to compute the strategic forecasts down to the operational schedules. Supply chain monitoring should be supported by ICT tools offering end-to-end supply chain visibility. Evolutionary characteristics of these monitoring tools are their real-time granularity and their end-to-end span of control, far beyond the first-tier supplier and customer.

## 4 Changing Logistics

It is clear that the consumer's dominance in the supply chain leads to inefficiencies. In Europe, on average, one truck on four drives empty and the fill rate of the non-empty trucks is hardly 57 %. This results in an overall inefficiency of 43 % (World Economic Forum 2009). In combination with the fact that road transport is the largest contributor to the carbon emissions, the outcome of all this bad news might not be supportive to create a good public image of the sector. The logistics sector is squeezed between the increasing consumer demands and the push to a more environmental-friendly society. Unfortunately, with the business models currently in place in the logistics sector, there is no evidence that this situation is about to improve in the coming years. First, it is expected that the devastating impact of the congestion will not be stopped immediately, as illustrated by the distance per hour covered by a truck, which is ceaselessly decreasing year after year in Europe (Schürmann et al. 2002). Second, transport has evolved to a commodity with very low or even no value creation for the consumer. The free transport in e-commerce is self-explanatory for this. Hence, carriers operate in an extremely low margin business where a killing competition rules.

Today, the externalities caused by transport are not internalized in the price of transport. Consequently, the cost of transport is comparatively way too cheap. The effect of too cheap transport combined with the huge wage differences worldwide have led to the current configurations of the global supply chains, where the goods are manufactured in low wage countries and subsequently transported to distribution hubs on the continents, from where distribution to the final customer is organized. Only the direct tangible costs and not the total supply chain costs are definitely driving these supply chain configurations. In some cases, the drive to minimize cost might even lead to very strange or odd configurations: shrimps caught in the Wadden Zee in the Netherlands are transported back and forth by truck to Morocco for being pealed; Belgian chocolates, made in Belgium are sent on a truck roundtrip to the Czech Republic for being co-packed. This demonstrates that the cost of transport is comparatively much too low to avoid exploitations of differences in the cost of labour.

While today, on average, a truck drives hardly for 55 % of its busy time, it is expected that this will further deteriorate because of increasing congestion-based waiting times on the one hand and increasing stress due to narrowing delivery time-windows at the sites of the shipper on the other hand. Accumulation of waiting times on the road, at the sites and at terminals, will further deteriorate the quality, the reliability and the forecastability of the supply chain.

Most shippers make use of, or even worse, exploit the strong competition among carriers and organize every 2 or 3 years big tenders in order to further obtain better tariffs. However, most shippers don't realize that the savings in transportation tariffs they obtained, are often offset by more hidden costs, like quality and service level deterioration, longer lead times and higher buffer inventories. Shippers should be encouraged to use the total supply chain cost principle to decide on supply chain wide, global savings instead of focussing on local improvements only.

Resource availability might become a serious problem in the next years. A shortage of drivers and warehouse workers could create a real problem of guaranteeing the necessary capacity for supply chain operations. The inflow of foreign labourers might not suffice to compensate retirement in the sector, especially in Western Europe. However, the first experiments with drones (e.g. DHL in 2013), unmanned trucks and platooning (i.e. The Netherlands in 2015), and with robotics in warehouses, especially those focussed on e-commerce, turned out to be very promising. Inversely, the risks related to this type of innovations is that at a certain point in time they would start to outperform traditional logistic service providers. Ultimately this might then lead to massive layoffs of human resources in logistics combined with severe cost cutting.

Capacity shortage is considered as a recurrent problem in logistics. Very often, capacity shortages are the result of unbalanced flows. Capacity expansion is often the simple, but ineffective response of the carriers in that case. However, this has shown repeatedly to be counterproductive and to create more inefficiencies and a further price deterioration.

Some specific sectors might be faced with a substantial decrease of their flows in the future. The digital availability of newspaper, magazines, documents, etc. will continue to reduce the need for often time-critical transport of hardcopies and documents. In the longer run, it can also be expected that 3D printing on an industrial scale would remove the need to transport some type of products, like spare parts or other printable items.

Finally, the environmental impact of transport is significant because it is a major user of energy, and burns most of the world's petroleum (World Economic Forum 2009). Transport, and more particularly road transport, is still the fastest-growing emission sector. Inversely, it goes without saying that any future emission tax imposed by public authorities will have a tremendous impact on transport and existing transport systems.

## 5 From Supply Chain 1.0 to 2.0

From the above future scenarios, it's clear that the supply chain world is standing at the eve of important, even disruptive, changes. Moreover, these changes will have a severe impact on the supply chains of many companies. As Keith Harrison, former Chief Product Supply Officer of Procter & Gamble, once said: "*Soaring energy costs are forcing P&G to re-think how to distribute its products... A lot of our supply chain work was implemented when oil was $10 a barrel... I could say that our supply chain design is now upside down... What is our business going to look like in 2015?*" It is clear that today, a lot of supply chains are not even ready to tackle the current problems and challenges adequately. This is simply illustrated by the struggle of some companies to embed the delivery of e-commerce shipments into their current distribution structures. Some other companies have been confronted with supply chain disruptions as a result of geopolitical problems in certain regions. These companies insufficiently or even never assessed the possible risks that might disrupt their deliveries. Most supply chains are not configured as resilient enough to manage this kind of disruption appropriately.

Very few companies have already prepared their supply chain for what is going to happen in the near future. It is to be expected that under societal and political pressure the cost of transport, and more precisely road transport, will increase through carbon taxes, traffic pricing mechanisms, higher excises, etc… Most probably, this will lead to more local sourcing and near shoring manufacturing and would require a major re-design and re-configuring of many supply chains that are not agile enough to digest change of this kind.

Nevertheless, a lot of companies start to realize that they have reached the limits of the Supply Chain version 1.0 on the supply chain maturity scale (see Fig. 1). The Supply Chain 1.0 is one with very limited integration between procurement, production and distribution and where an overall total supply chain cost concept is inexistent. This type of supply chain profile emerged during the *technology wave* at the end of last century and is characterized by being almost unilaterally cost-driven, sometimes even at the expense of service level concessions. Environmental sustainability is not really an option in Supply Chain 1.0. A good illustration of the working principle of this type of supply chain is the two-yearly tender processes for transport services launched by many global companies, in order to benchmark their transportation cost or to replace an existing carrier by a cheaper one. The result of such a process is often another 5–10 % savings on transportation cost. These cost savings are absorbed by the carriers and the logistics service providers, who are asked to provide the same service for less cost. In many cases the result of this all is

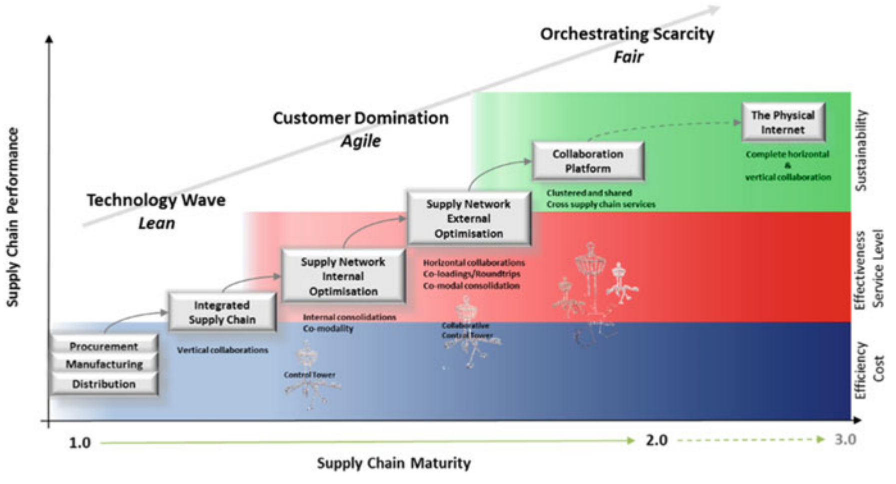



**Fig. 1** The supply chain maturity in societal and global perspective

a degradation of the service level offered by the carriers and logistics service providers. Finally, the 5–10 % transport cost savings is more than offset by an increase of other, hidden supply chain costs (longer lead times, more safety stocks,. . .) mainly due to a worsening of the service level. The subcontracting relation and not the long lasting partnership relation is another characteristic of the Supply Chain 1.0.

Since the beginning of this century, the world has entered the *customer-domination era*. Faster, smaller but more frequent on demand deliveries have become the new normal. Supply chains have been tuned to pay much more attention at customer service levels. A strong vertical integration with all supply chain partners, including suppliers and customers was a typical characteristic of this type of supply chain. With the ongoing boost of e-commerce, it is expected that the customer dominance might lead to excess. The "next day" and even "next hour" deliveries offered by e-tailers are pushing the supply chains to their limits with the unterminated request of the individual consumer for faster, fresher, cheaper, safer and completer on demand deliveries. However, nowadays, people start to realize that these supply chains are unable to provide appropriate solutions to relevant and major societal issues, like the scarcity of raw material, the spread of welfare, the world's food and water supply, the growth and aging of population and the urbanization. As the individual excess economy is now reaching its tilting point, the world has already started to shift towards a "share and circular economy". Environmental sustainability is there to become an at least equally important decision criterion as compared to efficiency and effectiveness. In this era, the scarcity needs to be orchestrated by means of highly performant cross-company supply chains and collaborative platforms. The so-called Supply Chain 2.0, should be able to manage gain and cost sharing in a circular economy. Already today, the collaboration platform is considered as one of the most optimal supply chain designs. A collaboration platform is a partnership in which logistic activities are clustered and resources are shared and pooled. Collaboration platforms can be industry specific, as in the case of the Belgian chocolates manufacturers who consolidate their warehousing, transport and co-packing activities. In other cases, the logistics of complementary products, like heavy with voluminous (e.g. heavy spare parts with voluminous baby drapers) can be consolidated, to optimize the fill rate of trucks, ships and trains.

It is clear that Supply Chain 2.0 is still only a target on the agenda of a lot of companies today. Unfortunately, most companies are closer to 1.0 than to 2.0. Consequently, they need to bridge a gap to become future-proof for the upcoming challenges. However, with the companies the awareness grows that it is absolutely necessary to start the journey towards Supply Chain 2.0 as soon as possible to have their supply chain adapted on time. Companies will have to plan their road to 2.0 carefully in order to seize all opportunities at improving their supply chain performance while they are evolving to a higher maturity level. These supply chain performance improvements will provide them a competitive advantage in the market.

Some authors expect that Supply Chain 3.0, or the Physical Internet, should be the ultimate supply chain maturity level in the long run. The Physical Internet applies the concepts of internet data transfer to real-world shipping processes, thus improving global logistics efficiency and sustainability (Montreuil 2011). Just like sending an e-mail through the internet, from provider to provider and hub to hub, by means of protocols, the same could be applied to freight transport. Sender and receiver of the goods don't care about the transport and warehouse providers alongside the trajectory, as long as the goods are delivered in the appropriate conditions, at the lowest cost and in the most sustainable way. Goods are transported in π-containers that are modular, eco-friendly, smart and standardized worldwide. The Internet of Things (IoT) guarantees the real-time track and trace of the containers in an interconnected network of certified infrastructure, protocols, logistics centres, hubs, information systems, regions, etc. (Sarraj et al. 2013).

## 6 Future-Proofing Diagnosis of the Supply Chain

As stated previously, a lot of companies are faced with a supply chain that would require an urgent re-design to cope with the upcoming problems and challenges described above. The starting point of such a strategic redesign would be a diagnosis of the status of the current supply chain in order to determine its maturity level.

In literature, only a few supply chain maturity models have been reported. The Supply Chain Management Process Maturity Models of Lockamy and McCormack (2004a, b) and McCormack (2001) measure the degree of process integration in the supply chain and are based on the Supply Chain Council's SCOR framework The Supply Chain Council (2010). The Supply Chain Capability map of Srai and Gregory (2005, 2008) evaluates the maturity of a multinational company's supply chain capabilities. A third model, proposed by Van Landeghem and Persoons (2001), is an audit scheme for logistical operations based on 84 best practices. Finally, Netland and Alfnes (2011) developed a maturity test for supply chain operations, based on 48 questions.

A somewhat different framework for performance measurement and benchmarking is offered by the Dow Jones Sustainability Index (DJSI). The DJSI is used to evaluate corporate economic, environmental and social performance, and to assess issues such as corporate governance, risk management, branding, climate change mitigation, supply chain standards and labour practices. The calculation of the DJSI and its geographic and industry-specific variants is based on a company assessment by means of an annual self-completed questionnaire and personal contact of a third party. A company gets listed on the DJSI and it is monitored daily. The index itself is a weighted average of scores on some economic, environmental and social dimensions (Dow Jones Sustainability Indices 2015). Searcy (2009) observed that in supply chain management sustainability indicators are still not widely used.

The test proposed here is different to the ones mentioned above. It is a diagnosis of the current state of the supply chain in the perspective of the upcoming trends and

**Table 1** The challenges with impact on the supply chain

| | Challenge |
|---|---|
| Changing environment | Demography |
| | Urbanization |
| | Globalization-glocalization |
| | The sharing economy |
| | The servitization economy |
| | The circular economy |
| | Corporate social value creation |
| | Supply chain risks |
| Changing customer behaviour | On demand |
| | Omni-channel |
| | Product innovation |
| | Speed of change in ICT technology |
| Changing logistics | Supply chain as a competitive advantage |
| | Manufacturing and process innovation |
| | Labour force |
| | Capacity shortage |
| | Co-modality |
| | Hybrid distribution structures |
| | Big data |
| | The physical internet |

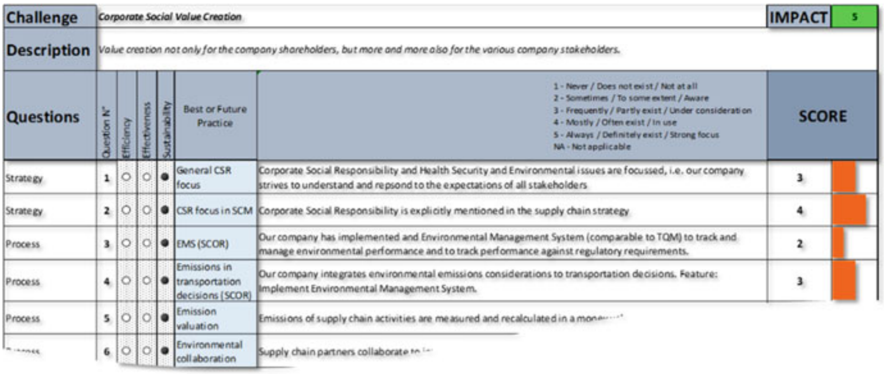
challenges in order to determine in how far a supply chain is future-proof against the major challenges.

In general and in order to guarantee the mass adoption of such a maturity test by industry, it should satisfy some requirements, including simplicity, not take too long to complete, not require large amount of detailed data, being industry-generic, using balanced dimensions of performance and being based on qualitative parameters (Netland and Alfnes 2011). These characteristics were taken into account while conceiving the test.

The framework of the test proposed here is designed to be dynamic and flexible. Table 1 represents the 20 challenges that have been selected to have a major future impact on supply chains. These challenges and their expected impact have been extensively described in this article. For every challenge, a sets of 10–14 questions have been developed to evaluate the impact on five possible supply chain areas:

1. Strategy
2. Organisation
3. Process
4. Control
5. Information

Hence, each question of the Future-proofing test is a combination of a challenge and an impact area, i.e. the level at which the challenge will impact the supply



| Challenge | Corporate Social Value Creation | | | | | | IMPACT | 5 |
|---|---|---|---|---|---|---|---|---|
| Description | Value creation not only for the company shareholders, but more and more also for the various company stakeholders. | | | | | | | |
| Questions | Question N° | Efficiency | Effectiveness | Sustainability | Best or Future Practice | 1 - Never / Does not exist / Not at all<br>2 - Sometimes / To some extent / Aware<br>3 - Frequently / Partly exist / Under consideration<br>4 - Mostly / Often exist / In use<br>5 - Always / Definitely exist / Strong focus<br>NA - Not applicable | SCORE | |
| Strategy | 1 | ○ | ○ | ● | General CSR focus | Corporate Social Responsibility and Health Security and Environmental issues are focussed, i.e. our company strives to understand and repsond to the expectations of all stakeholders | 3 | |
| Strategy | 2 | ○ | ○ | ● | CSR focus in SCM | Corporate Social Responsibility is explicitly mentioned in the supply chain strategy | 4 | |
| Process | 3 | ○ | ○ | ● | EMS (SCOR) | Our company has implemented and Environmental Management System (comparable to TQM) to track and manage environmental performance and to track performance against regulatory requirements. | 2 | |
| Process | 4 | ○ | ○ | ● | Emissions in transportation decisions (SCOR) | Our company integrates environmental emissions considerations to transportation decisions. Feature: Implement Environmental Management System. | 3 | |
| Process | 5 | ○ | ○ | ● | Emission valuation | Emissions of supply chain activities are measured and recalculated in a mon | | |
| [illegible] | 6 | ○ | ○ | ● | Environmental collaboration | Supply chain partners collaborate to | | |

**Fig. 2** Screen shot of the a set of questions of the future-proofing diagnosis

chain. The impact area is comparable to the decision area as defined by some other supply chain tests (Alfnes 2005; Lowson 2002; Netland and Alfnes 2011).

Each question needs to be answered with a score from 1 to 5. The use of a such a Lickert scale guarantees a sufficient level of nuance in the answers. This scale has been adapted from Netland and Alfnes (2011).

Figure 2 shows an example of a few questions of the challenge “Corporate Social Value Creation”.

## 7 Implementing the Future-Proofing Diagnosis

The key characteristics of the implementation scheme for the Future-Proofing Diagnosis are the previously mentioned requirements of simplicity, not take too long to complete, not require large amount of detailed data, being industry-generic, using balanced dimensions of performance and being based on qualitative parameters.

It is preferable, even recommended to have this diagnosis test conducted by a third party, external to the company. It can be either a consultant or an academician, for example. However, it is mandatory that the conductor should have sufficient expertise and moderator skills to lead the inspiration session.

Starting from Pendlebury et al.’s (1998) description of successful change management, based on the test process of Netland and Alfnes (2011)) and based on feedback of the validation study, this five-steps implementation scheme is proposed:

1. Inspire;
2. Prepare;
3. Complete;
4. Analyse;
5. Recommend.

The *Inspire* session is conceived as an interactive workshop with a panel composed of the company's key supply chain people. The aim of this session is to present all the challenges, to discuss them with the participants and finally to decide with the panel what the relevance and impact is of each challenge on the company's supply chain. Hence, at the end of the session each challenge is rated with a score:

1. No impact
2. Low Impact
3. Medium Impact
4. High Impact
5. Very High Impact

Not Applicable

During the *Prepare* session only the company's supply chain leader is asked to determine for each challenge, its level of ambition and that of its feasibility. This implies that for each challenge the following two questions need to be answered:

1. *Should we* be prepared to cope with this challenge, because it is important for our company?
2. *Would we* be able to prepare our company for this challenge?

The answer on both questions should be either "yes" or "no". At the end of the Prepare session, the example of Table 2 could be the outcome.

At this moment perceived mismatches, like a challenge of which the "IMPACT" is high or very high (score 4 or 5), the "We SHOULD" and the "We WOULD" are both at "NO", should be discussed and, if necessary, rectified in agreement with the supply chain leader.

The *Complete* session encompasses the actual scoring of the questions by the participants. Different configurations and setups could be envisaged, ranging from individual completion by each participant separately to a joint workshop sessions where each answer should be the consensus of all participants. Whatever setup is chosen, it is recommended to have the conductor reading and explaining each question to guarantee an appropriate and aligned interpretation by each participant. All questions are scored with a value from 1 to 5 and a Not Applicable category:

1. Never/Does not exist/Not at all
2. Sometimes/To some extent/Aware
3. Frequently/Partly exist/Under consideration
4. Mostly/Often exist/In use
5. Always/Definitely exist/Strong focus

Not Applicable

During the *Analyse* phase, the scores are aggregated, analysed and interpreted by an expert. Basically, the outcome of the test computes a "COULD WE?" score for

**Table 2** Example of the rating after the inspire and prepare sessions

| | CHALLENGE | IMPACT | We SHOULD | We WOULD |
|---|---|---|---|---|
| Changing environment | Demography | 4 | YES | YES |
| | Urbanization | 5 | YES | YES |
| | Globalization-glocalization | 3 | YES | NO |
| | The sharing economy | 3 | YES | NO |
| | The servitization economy | #N/A | #N/A | #N/A |
| | The circular economy | #N/A | #N/A | #N/A |
| | Corporate social value creation | 5 | YES | YES |
| | Supply chain risks | 5 | YES | NO |
| Changing customer behaviour | On demand | 3 | NO | NO |
| | Omni-channel | 3 | NO | NO |
| | Product innovation | 2 | YES | NO |
| | Speed of change in ICT technology | 3 | YES | NO |
| Changing logistics | Supply chain as a competitive advantage | 5 | YES | YES |
| | Manufacturing and process innovation | #N/A | #N/A | #N/A |
| | Labour force | 2 | YES | NO |
| | Capacity shortage | 4 | YES | YES |
| | Co-modality | 2 | YES | NO |
| | Hybrid distribution structures | 4 | YES | YES |
| | Big data | 2 | NO | NO |
| | The physical internet | 1 | YES | NO |

each challenge between 1 and 5, as the calculated average score of the applicable questions for that challenge. An example of an outcome table is proposed in Table 3. A gap analysis is performed by evaluating the "COULD WE?" score of each challenge in the perspective of its impact and its answers for the "We SHOULD" and "We WOULD" questions.

The analyst should pay special attention to challenges showing a gap. In general, a challenge with a low "COULD We?" score while "We SHOULD" is *YES* and/or a high or very high "IMPACT" needs to be addressed. The answers to the questions for that challenge should be analysed in detail in order to identify the reason why the company is actually lagging behind on that challenge. The analyst should try to determine from the questionnaire whether the poor performance is due to a lack of strategy, organisation, process, control or information, or a mix of these. Additional and more in-depth analyses might be required to obtain a complete and clear image of each gap. A spider graph, comparable to that of Fig. 3, might be supportive for identifying the reasons of the poor performance of the company on the challenge considered.

**Table 3** Example of the resulting scores of the future-proofing diagnosis

| | CHALLENGE | IMPACT | We SHOULD | We WOULD | Could We? |
|---|---|---|---|---|---|
| Changing environment | Demography | 4 | YES | YES | 3.3 |
| | Urbanization | 5 | YES | YES | 3.8 |
| | Globalization-glocalization | 3 | YES | NO | 2.0 |
| | The sharing economy | 3 | YES | NO | 1.0 |
| | The servitization economy | #N/A | #N/A | #N/A | #N/A |
| | The circular economy | #N/A | #N/A | #N/A | #N/A |
| | Corporate social value creation | 5 | YES | YES | 3.1 |
| | Supply chain risks | 5 | YES | NO | 3.0 |
| Changing customer behaviour | On demand | 3 | NO | NO | 3.0 |
| | Omni-channel | 3 | NO | NO | 4.0 |
| | Product innovation | 2 | YES | NO | 1.0 |
| | Speed of change in ICT technology | 3 | YES | NO | 3.0 |
| Changing logistics | Supply chain as a competitive advantage | 5 | YES | YES | 4.0 |
| | Manufacturing and process innovation | #N/A | #N/A | #N/A | #N/A |
| | Labour force | 2 | YES | NO | 3.0 |
| | Capacity shortage | 4 | YES | YES | 3.0 |
| | Co-modality | 2 | YES | NO | 2.0 |
| | Hybrid distribution structures | 4 | YES | YES | 3.0 |
| | Big data | 2 | NO | NO | 1.0 |
| | The physical internet | 1 | YES | NO | 1.0 |

The importance of the gap analysis should not be underestimated, because it provides the basis for the recommendations and could be fundamental to subsequent adaptations of the company's supply chain strategy.

In order to test whether there is a significant difference between the perceived importance of a challenge, reflected by its "IMPACT"-score and the company's readiness to cope with this challenge at this moment, represented by the "COULD WE?" score, a Wilcoxon signed rank test could be used.

The final stage of the Future-Proofing Diagnose encompasses the *Recommend* phase. The analyst interprets and translates the results of the gap analyses in a set of recommendations to the company. The *Recommend* deliverable includes a general statement, the so-called majors and minors and an overall estimation of the Supply Chain Maturity of the company. The general statement contains a reflection on the current status of the supply chain of the company and its readiness to cope with the upcoming challenges. Minors are quick wins that can be implemented immediately, while majors require a project-based approach to bridge one or more gaps.

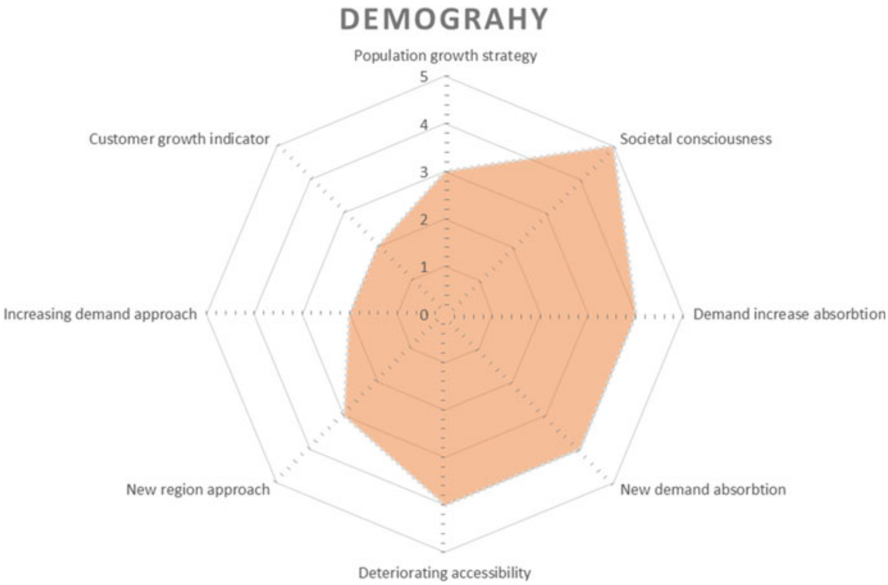



**Fig. 3** Example of a spider graph for the challenge "Demography"

The overall estimation of the Supply Chain Maturity is translated by the expert in a kind of estimated score between 1.0 and 2.0, representing the position of the company on the Supply Chain Maturity axis of the evolutionary graph of Fig. 1. The Supply Chain Maturity score is not a calculated value, but rather a global appreciation of the company's supply chain readiness to cope with the future challenges.

## 8 Validation Study

Before using the Future-Proofing Diagnosis as a full-fledged test tool for supply chains, some pilots were conducted at various companies in order to fine-tune the test. The major issues that were observed throughout the pre-tests are reported in this paragraph. The Future-Proofing Diagnosis has been fine-tuned accordingly.

The *Inspire* session turned out to be an eye-opener in many cases. The success and the interaction was largely dependent on the inspirer-conductor. Therefore, as this is the opening session and the first contact with the company's key supply chain people, it is mandatory to have an experienced and high qualified inspirer, who is able to stimulate and encourage the interaction while keeping an eye on the interaction-balance among the participants. To a certain extent, the size of the group did matter. The best interactive sessions were obtained with groups of four to eight people.

The inspirer should be able to explain in detail the impact of each future challenge on the supply chain in general and on the company's supply chain in particular. The participants of the pilots repeatedly expressed their interest in the insights and explanation given by the inspirer on how a particular challenge could really have an effect on the supply chain. This aspect of the inspiration session was really considered as valuable knowledge transfer by the companies.

The major issues observed during the *Prepare* session, were mainly related with the supply chain leader's interpretation of the difference between the "WE SHOULD" and the "WE COULD". In some cases, it took some time before the supply chain leader was able to make a clear distinction between both. Here too, the multiple roles of the conductor vis-à-vis the supply chain leader as peer, sounding board and counsellor should be underlined.

The observations made during the *Complete* sessions were mainly focussed on the way the questionnaires were filled out. Ideally, the same audience of the Inspiration session is asked to complete the questionnaire. New participants or substitutes should be avoided, as well as a too long delay between the Inspiration and the Complete sessions. Ideally, the delay should be no more than 1 week. However, this is not always feasible in global or big companies where the staff comes from different sites. It has been observed that the longer the delay between Inspire and Complete, the more the conductor is asked to give additional explanation for some of the questions. Inversely, organizing the Complete session immediately after the Inspire session is conceivable as long as the Prepare session could be intercalated.

The fill out of the questionnaire could be performed in different setups. Three major configurations could be envisaged:

- *Joint Workshop*: all participants are gathered in one room and the conductor processes the questions one by one. The participants should agree on a joint score for every question.
- *Individual Workshop*: all participants are gathered in one room and the conductor reads and, if necessary, comments the questions one by one. Each participant scores each question individually.
- *Individual*: each participant is asked to score all questions individually, before a certain deadline.

The Individual Workshop configuration should be the preferred configuration, because the support of the conductor guarantees the appropriate interpretation of the questions and the participants are totally free to score on each question. Moreover, variations in the scores of the questions among the participants could reveal additional insights during the analysis phase.

The anonymity of the participants can be best guaranteed in the Individual Workshop and the Individual setup. The Joint Workshop does not only result in less information because every question is rated only once, it could also be biased by the opinion of the leading persons in the group. The two workshop setups are highly time-consuming for the staff and is therefore sometimes difficult to realize in companies. For both workshop setups, almost a full day is required to complete the full diagnosis. During the pilots, a number of companies were in favour of the individual fill out of the questionnaire. A web-based questionnaire is recommended in these cases.

The *Analyse* session of the pilots was used to further check the validity and the integrity of the questionnaire. Besides, the relevance of some formal statistical tests was evaluated. As a result, the Wilcoxon signed rank test has been retained to measure the difference between the perceived importance of a challenge, reflected by its "IMPACT" score and the company's readiness to cope with this challenge at this moment, represented by the "COULD WE?" score. The ordinal Friedman test turned out to be useful to measure differences between the participants' scores in case of the Individual Workshop or the Individual configuration.

The gap analysis for each challenge appeared to contain the most valuable information for the supply chain leaders. During the *Recommendation* phase, the appropriate interpretation of the gap analysis by the conductor was considered as key for the supply chain leaders. Here again, the role of the conductor, his qualifications and experience were extremely important in the interpretation of the gap analysis and the subsequent discussions.

In short, the role of the inspirer-conductor turned out to be key during the pilots. It is highly recommended to keep the same person from start to finish, throughout the diagnosis project. Seniority, qualification, inspiration and presentation skills, and practical supply chain experience should be the required characteristics of the inspirer-conductor.

## 9 Conclusion

The accelerated rate of change in society and customer behaviour today enforces logistics and supply chains to transform accordingly. Today's customer on-demand dominance is becoming excessive, pushing the companies' supply chains to their limits, requiring more and more capacity and infrastructure. However, society is increasingly unwilling to further accept more logistics capacity and infrastructure that would cause irrevocable damage to people and planet. Consequently, future volume growth should be further accommodated with the existing logistics capacity and infrastructure, thus requiring much smarter supply chain management and logistics. The speed and intensity at which this evolution will take place depends on the impact of a number of challenges with which supply chains have to cope as from today. Twenty important challenges with an impact on supply chains have been identified. In order to help companies to prepare their supply chains for these challenges a methodological and dynamic framework is proposed, the Future-Proofing Supply Chain Diagnosis. The diagnosis gives a clear picture of the maturity level of a company's supply chain and its readiness to cope with the upcoming challenges.

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## References

Alfnes E (2005) Enterprise reengineering: a strategic framework and methodology. Norges teknisk-naturvitenskapelige universitet, Trondheim

Baines TS, Lightfoot HW, Benedettini O, Kay JM (2009) The servitization of manufacturing: a review of literature and reflection on future challenges. J Manuf Technol Manage 20(5): 547–567

Baines TS (2013) Servitization impact study: how UK based manufacturing organisations are transforming themselves to compete through advanced services. Aston Centre for Servitization Research and Practice, Aston Business School, Birmingham, UK

Ballou RH (2004) Business logistics/supply chain management. Pearson Prentice Hall, Englewood Cliffs, NJ

$CO^3$—Collaborative Concepts for Co-modality (2014) http://www.co3-project.eu

Dow Jones Sustainability Indices (2015) http://www.sustainability-indices.com

Finisterra Do Paço AM, Raposo MLB, Filho WL (2009) Identifying the green consumer: a segmentation study. J Target Meas Anal Market 17:17–25

Frost & Sullivan Research Service (2013) Global mega trends and their implications on urban logistics: global spending on urban logistics to reach $5.980 Trillion by 2020, 144p

Global Commerce Initiatives and Capgemini (2008) 2016–Future supply chain, 52p

Grandjot H-H (2006) Risikomanagement aus betrieblicher Sicht in einem Logistikunternehmen. In: Hector B (ed) Risikomanagement in der Logistik. Deutscher Verkehrs-Verlag, Hamburg

Handfield R, Sroufe R, Walton S (2005) Integrating environmental management and supply chain strategies. Bus Strat Environ 14:1–19

Hendricks KB, Singhal VR (2005) An empirical analysis of the effect of supply chain disruptions on long-run stock price performance and equity risk of the firm. Prod Oper Manage 14(1): 35–52

Jaberidoost M, Nikfar S, Abdollahias A, Dinarvand R (2013) Pharmaceutical supply chain risks: a systematic review. DARU J Pharm Sci 21(1):69

Lasserre F (2004) Logistics and the Internet: transportation and location issues are crucial in the logistics chain. J Transp Geogr 12:73–84

Lockamy AI, McCormack K (2004a) The development of a supply chain management process maturity model using the concepts of business process orientation. Int J Supply Chain Manage 9(4):272–278

Lockamy AI, McCormack K (2004b) Linking SCOR planning practices to supply chain performance: an exploratory study. Int J Oper Prod Manage 24(12):1192–1218

Lowson RH (2002) Strategic operations management: the new competitive advantage. Routledge, London

McCormack K (2001) Supply chain maturity assessment: a road-map for building the extended supply chain. Supply Chain Pract 3(4):4–21

Montreuil B (2011) Towards a Physical internet: meeting the global logistics sustainability grand challenge. Logist Res 3(2–3):71–87

Netland TH, Alfnes E (2011) Proposing a quick best practice maturity test for supply chain operations. Meas Bus Excell 15(1):66–76

Pendlebury J, Grouard B, Meston F (1998) The ten keys to successful change management. Wiley, Chichester

Piecyk MI, McKinnon A (2010) Forecasting the carbon footprint of road freight transport in 2020. Int J Prod Econ 128:31–42

Sarraj R, Ballot E, Pan S, Hakimi D, Montreuil B (2013) Interconnected logistic networks and protocols: simulation-based efficiency assessment. Int J Prod Res 52(11):3185–3208

Searcy C (2009) The role of sustainable development indicators in corporate decision-making. International Institute for Sustainable Development, Manitoba, 27p

Schürmann C, Spiekermann K, Wegener M (2002) Trans-European transport networks and regional economic development. In: Proceedings of the 42nd Congress of the European Regional Science Association (ERSA). ERSA, Dortmund

Sharma SK, Bhat A (2014) Supply chain risks: development of model and empirical evidence. Int J Appl Manage Sci 6(1):45–64

Soni G, Kodali R (2008) Evolution of supply chain management: development in academia and industry. ICFAI J Supply Chain Manage 40(4):7–40

Srai J, Gregory M (2005) Supply chain capability assessment of global operations using maturity models. In Demeter K (ed) Proceedings of EurOMA 2005 operations and global competitiveness, Budapest, 19–22 June. Diamond Congress, Budapest, pp 949–958

Srai J, Gregory M (2008) A supply network configuration perspective on international supply chain development. Int J Oper Prod Manage 28:386–411

Stank T, Burnette M, Dittman P (2014) Global supply chains. The Global Supply Chain Institute, The University of Tennessee, Knoxville, 52pp

Tetteh A, Qi X (2014) Supply chain distribution networks: single-, dual- & omni-channel. Interdiscipl J Res Bus 3(9):63–73

The Supply Chain Council (2010) SCOR: the supply chain reference, version 10

Von der Gracht HA, Darkow I-L (2013) The future role of logistics for global wealth–scenarios and discontinuities until 2025. Foresight 15(5):405–419

Van Landeghem R, Persoons K (2001) Benchmarking of logistical operations based on a causal model. Int J Oper Prod Manage 21(1/2):254–267

World Economic Forum (2009) Supply chain decarbonisation. World Economic Forum, Geneva, 41pp

World Economic Forum (2012) New models for addressing supply chain and transport risk. World Economic Forum, Geneva, 26pp

World Economic Forum (2014) Towards the circular economy: accelerating the scale-up across global supply chains. World Economic Forum, Geneva, 44pp

World Economic Forum (2015) Global risks 2015–a global risk network report. World Economic Forum, Geneva, 69pp

United Nations (2013) World population prospects, the 2012 revision, 118pp

United Nations (2014) World urbanization prospects, the 2014 revision, 32pp

# Gain Sharing in Horizontal Logistic Co-operation: A Case Study in the Fresh Fruit and Vegetables Sector

**Christof Defryn, Christine Vanovermeire, and Kenneth Sörensen**

**Abstract** More and more companies start to notice the potential of setting up a logistic co-operation. They realize however that this idea is also a source of new challenges and impediments. We will focus on the challenge of dividing the total coalition gain among all partners. In this chapter, we show that significant differences exist between allocation methods and we examine the impact of defining gain defining gain sharing on a short term (daily) or a long term (monthly) basis. Too often, the selection of an appropriate allocation mechanism is considered as an independent decision with *fairness* as the single criterion. The companies involved, however, should realize what the impact of a certain allocation method might be, when applied in the broader context of horizontal co-operation. A selection of well known allocation methods and concepts is introduced and applied to a real life case study of fresh produce traders, jointly organising their transportation from the auction to a joint transport platform.

## 1 Introduction and Literature Review

### *1.1 Gain Sharing in Horizontal Logistics Co-operations*

In order to improve the efficiency of transportation networks and in light of the growing debate on sustainability many initiatives have been taken, including the idea of *horizontal co-operation*, where companies at the same level of the supply chain join forces (European Commission 2011). The positive effect of such co-operations has been shown by means of simulation (Hageback and Segerstedt 2004; Cruijssen and Salomon 2004; Palander and Väätäinen 2005; Le Blanc et al. 2006; Ergun et al. 2007) and by reporting on actual cases (Bahrami 2002; Wiegmans 2005; Cruijssen et al. 2007; Frisk et al. 2010).

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Horizontal co-operation in logistics is gaining traction as a viable way to reduce transportation costs and increase efficiency and sustainability. By combining the shipments of several companies, the number of trucks on the road can be reduced and their fill rate can be increased (European Commission 2011; Initiative and Capgemini 2008). The main motivation for companies to collaborate is the fact that the total transportation cost of the coalition is lower than the sum of the stand-alone costs. The difference between these costs is called the *coalition gain*, and needs to be divided among the different partners.

However, before a successful co-operation can be established, the partners involved have to overcome certain barriers (Cruijssen et al. 2007). Multiple initiatives arise (e.g. $CO^3$-project, LOG2020,. . .), bringing together the peer groups from the industry and catalysing the debate on related topics (Cruijssen et al. 2014; Lu and Liesa 2013). We can conclude that one of main challenges is to ensure a fair allocation of the benefits to all partners, next to finding the right partner(s) and a reliable third party that can coordinate the co-operation in such a way that all participants are satisfied (often referred to as the *neutral trustee*). In this chapter, we will focus on the question of gain sharing.

When gains are generated as a result of co-operation between different partners, it is not trivial to determine which partner has a right to which fraction of these gains. In the current literature, the focus lies on the formulation of the concept of *fairness* by questioning which allocation is *fair* for every partner in the coalition. Different definitions of the fairness criteria have resulted in a large set of *gain sharing methods*—also called *profit allocation methods*—going from straightforward rules of thumb to more complicated concepts described in the game theory literature. Rather than dividing the coalition gain between the partners, the coalition can also agree to share the total cost. In this case, a *cost allocation method* is used. Although all cost allocation methods can also be used to allocate the profit, the result for each partner is generally not the same, and the decision to allocate the coalition gain or the coalition cost should be taken with caution.

In this chapter, a new approach is introduced that can help a coalition in choosing the appropriate allocation mechanism. Instead of focusing on fairness, which remains rather subjective, we argue that gain sharing should be evaluated within the broader idea of horizontal co-operation. As for every gain sharing method certain partner characteristics are favoured, the coalition as a whole implicitly imposes the incentive to the partners to score well on these characteristics. Some coalitions will wish to encourage the partners to take a flexible stance with respect to their delivery terms (e.g. wide time windows, orders that can be delivered on different days), whereas others will prefer partners to ship as much as possible.

This approach is studied on real life data, provided by a coalition of produce traders (see Sect. 2). The selected gain sharing methods are the *Shapley value*, the *Nucleolus*, the *Equal Profit Method (EPM)* and the *Alternative Cost Avoided Method* (ACAM). The results of these allocation methods are compared to each other, and to the *Volume-based method*, that is currently used in this particular horizontal co-operation.

**Table 1** Properties of the different allocation mechanisms

| Property | Definition | Shapley | Nucleolus | ACAM | EPM | Volume |
|---|---|---|---|---|---|---|
| Pareto-efficiency | The exact total cost (or profit) should be allocated among te partners | √ | √ | √ | √ | √ |
| Individual rationality | A player should not be allocated a cost that is higher than its stand-alone cost | √ | √ | √ | – | – |
| Stability | Individual rationality is ensured for every sub-coalition | – | √ | – | – | – |
| Additivity | The allocation can not be influenced by making larger coalitions in advance. The profits, allocated to company $i$ and $j$, are therefore equal to the profit a company would receive that represents $i + j$ | √ | – | – | – | – |
| Dummy player property | A partner that neither helps nor harms any coalition is allocated a zero-profit or a cost equal to its stand-alone cost | √ | √ | – | – | – |

## 1.2 *Properties of Gain Sharing*

In the field of game theory a number of properties have been formulated that are considered important when evaluating a profit (or cost) allocation (Tijs and Driessen 1986). The most important ones are described in Table 1. Furthermore, we indicated which allocation method, discussed in this chapter, possesses the described property.

In the remainder of this section, each cost allocation method is briefly introduced. Table 2 contains the symbols used in this chapter.

## 1.3 *Methods for Gain Sharing*

In this section, the selected allocation methods are introduced briefly. For a more elaborate review on gain sharing methods, we refer to Vanovermeire et al. (2014).

### 1.3.1 The Shapley Value

The formation of the grand coalition can be seen as a sequential process, where the partners enter one by one (Tijs and Driessen 1986). Each time, a partner pays the

**Table 2** List of symbols

| | |
|---|---|
| $N$ = the complete coalition with all partners | $m_i$ = the marginal contribution of partner $i$ |
| $S$ = a sub-coalition ($S \subseteq N$) | $w_i$ = the weight indicating the proportion of the gain partner $i$ receives |
| $\|S\|$ = the number of partners in coalition $S$ | $x$ = vector of allocated gains |
| $i, j$ = indices of different partners in a coalition | $x_i$ = the allocated gain for partner $i$ |
| $s(i)$ = the stand-alone cost of partner $i$ | $V_i$ = the volume of partner $i$ |
| $e(.)$ = the excess of an allocation | |
| $c(.)$ = the cost of a coalition | |

additional costs that arise by joining its predecessors. If this is repeated for any possible permutation of the order of entering, and the obtained costs are averaged in a uniform manner, the *Shapley cost allocation method* is obtained. This method is based on the *Shapley value*, introduced by Shapley (1953).

Because the Shapley value takes into account the marginal effect of a partner on *all (sub)coalitions* it is said to be based entirely on a partner's *co-operative productivity*. The portion of the cost assigned to partner $i$ is given by the following formula:

$$x_i = \sum\nolimits_{S \subseteq N \setminus i} \frac{|S|!(|N| - |S| - 1)!}{|N|!} (c(S \cup i) - c(S)) \tag{1}$$

Using the Shapley value as an allocation method is increasingly popular, in part because it has been put forward by the European $CO^3$-project,[1] a peer group of more than 50 important industrial companies. This project, co-financed by the Directorate-General for Research and Innovation of the European Commission, strives to encourage a structural breakthrough in the competitiveness and sustainability of European logistics by stimulating horizontal co-operation between European shippers. Nevertheless, the $CO^3$-consortium also acknowledges the need to select a gain or cost allocation mechanism on a case-by-case approach (Biermasz 2012).

### 1.3.2 The Nucleolus

The Nucleolus, defined by Schmeidler (1969), is a cost allocation mechanism based on the idea of *minimizing maximum 'unhappiness'* of the partners. Unhappiness is measured by the *excess* of the proposed allocation, defined as:

[1] www.co3-project.eu

$$e(x, S) = c(S) - \sum\nolimits_{i \in S} x_i \tag{2}$$

The excess can be interpreted as the gain that the companies in sub-coalition $S$ obtain if they withdraw from the grand coalition $N$. To evaluate different allocations based on the excess, a number of linear programs (LPs) need to be solved. For increasing coalition sizes, these LPs increase in complexity and computation time. Nevertheless, a unique and stable solution is guaranteed in the centre of the core.

### 1.3.3 The Equal Profit Method

A more intuitive way of dividing the coalition gain is based on the idea of *equal profit*. Frisk et al. (2010) proposed this method in order to obtain relative savings as equal as possible for the different partners. The calculations can be done by solving a straightforward linear program that minimises the largest relative savings difference between any pair of partners. The EPM can only be calculated if the core is non-empty. In this case a stable solution is guaranteed.

It can be argued that it might seem 'fair' to offer the same relative savings to every partner in the coalition. However, the equal profit method uses the stand-alone cost to define the relative importance of each partner. As a result, companies with higher stand-alone costs receive a bigger absolute part of the coalition gain when the method is used for gain sharing.

### 1.3.4 The Alternative Cost Avoided Method

As discussed by Tijs and Driessen (1986), a sub-group of allocation methods is based on the principle of first dividing the total coalition gain in a *separable* ($m_i$) and a *non-separable part* $\left(c(N) - \sum_j m_j\right)$. The first part, linked to one specific partner, is defined as the *marginal cost when that partner enters the coalition consisting of all other partners* (Vanovermeire et al. 2014). The remaining, non-separable, part can then be divided in various ways. Based on the individual contributions of each partner, the *alternative cost avoided method* (ACAM) defines a set of weights that can be used to divide of the non-separable costs. These weights are based on the differences between the stand-alone cost $s(i)$ and the marginal cost $m_i$ of a partner. The part of the total coalition cost allocated to partner $i$, is thus:

$$x_i = m_i + \left(c(N) - \sum_j m_j\right) \frac{s(i) - m_i}{\sum_j \left(s(j) - m_j\right)} \tag{3}$$

### 1.3.5 Volume-Based Allocation

In practice, companies mostly stick to the more straightforward allocation methods that can be easily interpreted and offer a certain transparency (Frisk et al. 2010). For these *proportional allocation methods* the coalition gains are divided by calculating a weight for each partner. When a volume-based allocation is used these weights are based on the volume, e.g. the number of pallets, the total weight, . . ., shipped by that partner with respect to the total coalition volume see Eq. (4). This method is currently used by the fresh produce shuttle service.

$$w_i = \frac{V_i}{\sum_i V_i} \tag{4}$$

## 2 Co-operation Among Fresh Produce Traders

Fresh fruit and vegetables are typically traded at an auction from which they are transported to the customers in temperature controlled trucks. Fresh produce is highly perishable and an efficient supply chain is of crucial importance to maintain customer service levels.

In 2012, three traders at a Belgian fruit and vegetables auction launched, under the supervision of a neutral third party, a joint shuttle service between the auction and the traders common transport platform, about 250 km to the east. This shuttle service was outsourced to a specialized logistics service provider (LSP).

A twofold, positive effect could be observed. First, the shuttle service guaranteed the traders that their goods, even the ones bought last-minute, can be transported in an appropriate way. A reliable truck, departing no later than 11.00 am from the quay at the auction, provided the necessary temperature controlled (8 °C) transportation. Furthermore, by combining the orders of the three traders and thereby increasing the transported volume, better prices could be negotiated from the LSP.

A yielding pace list was negotiated that determined the transportation price as a function of the total shipped order size (i.e., the number of pallets). The regressive character of this instrument was meant to stimulate the traders to increase their order quantities. Since the total cost of the shuttle truck is calculated based on the consolidated volume, the traders are pushed to avoid small shipments by buying extra products at the auction or by moving their delivery to the next day, if feasible.

From their side, the auction authorities encourage this horizontal co-operation project in two ways. First, priority is given to the shuttle service by assigning a specific quay to it. Secondly, the auction also acts as a neutral party by keeping track of the consolidation gains (i.e., the profit obtained by switching from individual transport to the shuttle service). Periodically, these gains are divided among the traders, using the Volume method, i.e., proportional to the number of traded pallets.

In this chapter, we scrutinize the way in which the consolidation gains are divided by the agreement between the traders. Next to the current way of working, we examine the properties and results of the gain sharing methods discussed in Sect. 1.3. We find that different gain sharing mechanisms give largely different results, and also result in different incentives for the partners in the coalition. For these reasons, we conclude that it is important to select an adequate gain sharing mechanism.

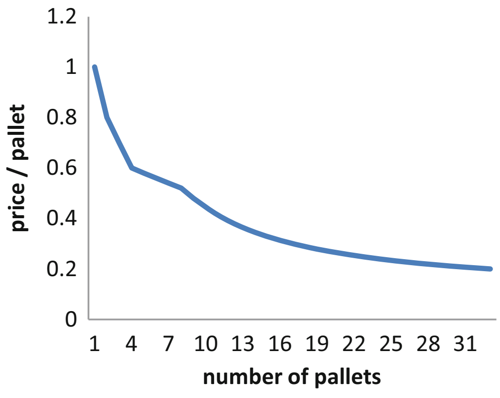
## 3 Simulation Results

The shipped volumes of the coalition were observed during a period of 8 weeks. The cost of every (sub)-coalition is calculated based on the pace list (Fig. 1), negotiated with the logistics service provider.[2] In case of multiple trucks on 1 day an optimal load distribution with minimal total costs is assumed. A full truck load consists of 33 pallets.

The parties involved agreed on a volume-based gain sharing method, because of simplicity and transparency reasons. The traders receive a part of the coalition gain according to their individual volumes, calculated by the number of pallets, which gives them the incentive to place larger orders. The profits, held by the auction authorities as a neutral party, are periodically divided among the traders. The logistics service provider is paid according to the consolidated volumes. During the considered period of 8 weeks, the total coalition gain reached more than 2000 €, which corresponds to a global cost reduction of 16 %.

In this section, the characteristics of the different partners are introduced (Sect. 3.1) and the need for a gain sharing method that produces a stable allocation is discussed (Sect. 3.2). The difference between gain sharing on a day-to-day basis

**Fig. 1** The relative pace list for the traders' shuttle truck




[2] The pace list is anonymised by normalising it between 0 and 1.

or on an aggregated (e.g. weekly) basis is shown in Sect. 3.3. Finally, Sect. 3.4 handles the difference between the original rigid scenario and a flexible scenario where partners accept that small orders are stored at the auction and delivered the next morning in order to avoid the higher price per pallet for small order sizes.

### *3.1 Characteristics of the Partners*

The shuttle truck service is shared by three partners (A, B and C). The first partner (A) transports high volumes (61 % of the total volume of the coalition) and nearly every day. Therefore, this partners requires a full truckloads (FTL) on a regular basis. As no bundling is possible with these shipments, FTLs are not beneficial for the total coalition.

Partner B also makes use of the shuttle truck on a very regular basis, but with lower average order sizes. In the stand-alone scenario this will result in a higher cost per pallet. By combining the orders with other partners, significant synergies can be expected. Because orders of partner B are less-than-truckload, they can be combined more easily with other less-than-truckload orders.

Lastly, the third partner (C) also places small orders that can be combined easily with other partners. However, the degree of participation is rather low for this partner (only 9 % of the total volume, and 30 % of the transports) reducing again his impact on the synergy of the total coalition.

### *3.2 Stability*

When setting up a new coalition, the potential partners need to take into account the stability of the grand coalition. If a sub-coalition exists that is in any way more beneficial for one collaborating partner, than the long-term stability of the grand coalition can no longer be guaranteed. Stability is ensured in two ways.

Firstly, the gain of a sub-coalition may never exceed the total coalition gain. If this is the case, a better performing sub-coalition could be formed by leaving out some partners. This is known as the problem of *strong sub-coalitions* (Vanovermeire et al. 2014). For the shuttle truck case, studied in this chapter, it can be seen in Table 3 that the total cost of a (sub)-coalition is always smaller than the summed stand-alone costs of the partners involved. Additionally it is clear that by forming the grand coalition (A–B–C) the highest gains are obtained. Although the stability of the aggregate data, it remains possible that on a daily basis non-stable co-operations existed. In the sample studied in this chapter, one observation involved a strong sub-coalition. On this day, a co-operation of only two partners would generate a higher profit, compared to the current situation that includes all three partners. This possible short-term instability does not necessary endanger the long-term stability of the total coalition and is rather rare and

**Table 3** Aggregated total cost of the (sub)-coalitions for the shuttle truck case study

| Sub-coalitions | | A | B | C | A–B | B–C | A–C | A–B–C |
|---|---|---|---|---|---|---|---|---|
| Original | Cost | 6142 € | 4844 € | 1646 € | 9847 € | 5733 € | 7441 € | 10564 € |
| | Profit | | | | 1138 € | 757 € | 347 € | 2068 € |
| Flexible | Cost | 6096 € | 4680 € | 1475 € | 9548 € | 5400 € | 7038 € | 10110 € |
| | Profit | | | | 1229 € | 756 € | 534 € | 2142 € |

temporary. However, it causes an infeasible solution for the equal profit allocation method for this 1 day.

Secondly, the allocation mechanisms need to ensure that the costs paid by the different partners in the grand coalition are always lower than the corresponding stand-alone costs. In Sect. 1.2 this idea was introduced as the property of individual rationality. If this property is not fulfilled, a partner may not want to collaborate and the grand coalition may split up.

In Table 1 in Sect. 1.2 it can be seen that only one of the five allocation methods proposed in this chapter, the Nucleolus, guarantees a stable solution. Even the less restrictive property of individual rationality is not guaranteed in some of the methods. However, it might be useful to remark that, although it is not guaranteed mathematically, all results obtained for this case study are individual rational—no partner is allocated a negative profit—and stable—except for 1 day, as described above.

### *3.3 Aggregation of Profit Allocation*

Depending on the allocation method, a different division of the profits is realized when the allocation takes place on a daily basis or on aggregate level (e.g. weekly or monthly). These differences between the allocation methods are demonstrated in Table 4a.

For the Shapley value, the Nucleolus and ACAM, similar results are reported in the rigid planning method on a daily basis. This is due to the fact that most of the time only two partners make use of the shuttle truck on the same day. In a coalition with only two partners, these three allocation methods split the profit in two equal parts. The volume-based allocation and the equal profit method however differ, allocating less to the smaller partners, B and C, in favour of partner A.

Significant differences are found comparing daily allocation with respect to aggregated allocation. On aggregate level the gains are divided among the three partners based on their total contribution during the period. Due to the aggregation, the multiple two-party co-operations that are observed will be summed and the Shapley Value, Nucleolus and ACAM no longer divide the gains equally among the partners. Here, the Nucleolus tends to allocate more to partner A, due to his higher stand-alone cost and the property of finding a solution in the centre of the core.

**Table 4** Allocation of coalition gain by the different methods. For the aggregated allocation we assume that the cost allocation is only performed at the end of the 8-week sample

| | Daily allocation | | | Aggregated allocation | | |
|---|---|---|---|---|---|---|
| | A | B | C | A | B | C |
| (a) Rigid planning (total profit = 2068 €) | | | | | | |
| Volume | 1034 € | 673 € | 361 € | 1264 € | 611 € | 193 € |
| Shapley | 684 € | 891 € | 494 € | 684 € | 890 € | 494 € |
| Nucleolus | 684 € | 976 € | 409 € | 846 € | 757 € | 464 € |
| ACAM | 685 € | 893 € | 495 € | 684 € | 898 € | 485 € |
| EPM | 866 € | 792 € | 411 € | 1005 € | 793 € | 269 € |
| (b) Flexible planning (total profit = 2142 €) | | | | | | |
| Volume | 1097 € | 692 € | 353 € | 1309 € | 632 € | 200 € |
| Shapley | 756 € | 868 € | 520 € | 756 € | 867 € | 519 € |
| Nucleolus | 731 € | 953 € | 459 € | 930 € | 756 € | 457 € |
| ACAM | 734 € | 851 € | 559 € | 741 € | 876 € | 498 € |
| EPM | 909 € | 746 € | 387 € | 1050 € | 810 € | 255 € |

It can be argued that a daily allocation gives a better approximation of the real costs and profits per partner. Aggregating costs flattens the real costs of single transports, which is thus taken less into account when calculating the profit allocation. The differences between daily and aggregated allocation can be up to 46 %.

Exceptionally, the Shapley value, because of the property of additivity that this method possesses and the fact that it is fully based on efficiency of the transportation, is insensitive to the level of aggregation.

## *3.4 Flexibility to Support the Coalition*

The price that is to be paid by the traders for the transport depends on the shipped volume according to a negotiated pace list, which makes smaller shipments rather costly. In order to avoid high transportation costs the coalition has agreed to strive towards shipments of at least ten pallets. If this threshold is not reached the traders are motivated to buy extra products or to delay the delivery by 1 day if possible.

In our simulations, two alternative scenarios are considered. In the *rigid* scenario—Table 5a—all orders are shipped on the day they are placed (which is the current situation). The *flexible* scenario—Table 5b—assumes that small order sizes (less than ten pallets) can be stored at the auction for 1 day and combined in the next day truck if this yields a smaller total cost.

In reality, during the 8 weeks of observation, postponement of the transport occurred only once. Therefore, it is simulated that orders of less than ten pallets are

**Table 5** One-week sample of shipped volumes per partner and for the grand coalition

| | Volume | | | Grand coalition (A + B + C) | |
|---|---|---|---|---|---|
| | A | B | C | Volume | Coalition cost |
| (a) Rigid planning | | | | | |
| Day 1 | 3 × 33 | 10 | | 3 × 33 + 10 | 1212.7 € |
| Day 2 | | 5 | 4 | 9 | 219 € |
| Day 3 | 13 | 22 | | 33 + 2 | 410 € |
| Day 4 | | | | | |
| Day 5 | 11 | 10 | 10 | 31 | 320.54 € |
| Aggregated | 123 | 47 | 14 | 184 | 2159.24 € |
| (b) Flexible planning | | | | | |
| Day 1 | 3 × 33 | 10 | | 3 × 33 + 10 | 1212.7 € |
| Day 2 | | | | | |
| Day 3 | 13 | 22 + 5 | 4 | 33 + 11 | 557.37 € |
| Day 4 | | | | | |
| Day 5 | 11 | 10 | 10 | 31 | 320.54 € |
| Aggregated | 123 | 47 | 14 | 184 | 2090.61 € |

automatically moved to the next day, increasing the possibilities of combining orders. Table 5b contains an example of this practice. As the small volume that is to be shipped on day 2 is relatively expensive, the flexible scenario imposes that these pallets stay at the auction for one more day and are shipped the next morning. Although the total cost of the coalition is lower when flexibility is enforced, the coalition gain might decrease. This is due the fact that the stand-alone cost of the partners also decreases when flexibility is enforced. Nevertheless, because of the lower total coalition cost, the flexible approach will still be beneficial for the coalition.

According to Table 3, a flexible approach to the entire 8-week data set, increases the coalition gain with 74 € (from 2068 € to 2142 €). An additional decrease in total coalition cost of around 4.3 % can be witnessed by imposing the flexible strategy instead of the original scenario. The transport is postponed to the next day in 12.5 % of the reported days.

The allocated profits for the flexible scenario are shown in Table 4b. Depending on the chosen allocation mechanism, this flexible strategy turns out to be not that profitable for every partner in the shuttle truck case study. Most of the time, the flexible strategy is less beneficial for partner B.

As the order sizes of B are rather small, a flexible behaviour of B will in the place result in an improved stand-alone position. For partners A and C, this flexibility will affect their stand-alone position less. For partner A, this is due to the fact that its volumes are already large most of the times, so they are shipped anyway. Partner C is not shipping regularly, so leaving its orders at the auction will not lead to any improvement as the probability that this partner will ship again the next day is low. We can therefore state that for partners A and C only benefits are created when the co-operation is set up. This positive effect on the coalition is captured by the

Shapley Value, Nucleolus and ACAM. For the Volume and the Equal profit method, the shipping day is not important and the gains are allocated pro rata. The drop in allocated gain for partner C by using the EPM in the flexible scenario is only due to the 1 day with strong sub-coalitions, as explained in Sect. 3.2. For this day, the EPM can not be calculated.

## 4 A Different Allocation Method, a Different Incentive

Every gain sharing method takes as an input a limited number of parameters and partner characteristics to obtain the final profit that is allocated to every partner. In Sect. 1.3 it could be seen that the Shapley value method is based only on costs, where the volume-based method does only take the shipped volume into account. Similar to the Shapley value, the ACAM is also based on costs but it does not include all possible sub-coalitions. This can also be said for the Nucleolus, but from a completely different perspective. The EPM is not based on absolute costs or profits, but divides the gains based on their relative differences. We can therefore state that by choosing a gain sharing method, a certain incentive is given to the partners in the coalition. Because if they are able to improve on the characteristics that are taken into account by the allocation method, a higher gain can be allocated to this partner. This idea is summarised in Table 6.

If the *volume-based allocation* is chosen, the partners shipping the highest volumes are favoured although their shipments might not be that efficient for the coalition. This method therefore gives an incentive to grow. The *ACAM* produces similar results compared to the *Shapley value*. This last one puts a lot of stress on efficiency by taking into account the marginal cost of the different partners in *every* (sub)-coalition. Here, the efficiency of a single partner (e.g. the partner is participating a lot and the order sizes leave enough room for combining with others) is rewarded. The *Nucleolus* refers to long term stability because a solution in the centre of the core is guaranteed. Therefore, no partner feels the incentive to abandon

**Table 6** The incentives of different gain sharing methods

| Allocation method | Partner characteristics | Incentive |
|---|---|---|
| Shapley value | Stand-alone cost | Efficiency |
| | Cost of all sub-coalitions | |
| Nucleolus | Stand-alone cost | Stability |
| | Cost of sub-coalitions with $\|N\| - 1$ partners | |
| Equal profit method | Stand-alone cost | Stand-alone inefficiency |
| Alternative cost avoided method | Stand-alone cost | Efficiency |
| | Cost of sub-coalitions with $\|N\| - 1$ partners | |
| Volume-based allocation | Volume | Ship large volumes |

the grand coalition. By stabilizing as much as possible the situation as it is, it will give no incentive to the partners to adapt their behaviour. We therefore state that the Nucleolus gives an incentive of stability to the partners. In contrast to the Shapley Value and the ACAM, the Nucleolus is less steadfast when gains are divided periodically. In both the rigid and the flexible scenario, we observe a significant divergence on the aggregate level where the method is less sensitive for day to day efficiency of the transport. Lastly, the *Equal Profit Method* can only be calculated if the coalition is stable. Although we find that for this case study the coalition remains stable in the long run, the stability cannot be guaranteed every single day. It can also be seen that, because of the fact the EPM uses relative savings, partners with a high total stand-alone cost, that are therefore inefficient, are favoured at the expense of the efficient ones. It can be argued that this might result in an unfair allocation if the partners differ significantly.

## 5 Concluding Remarks and Further Research

In this chapter, the effect of the selected gain sharing method in a horizontal co-operation is examined by using an empirical approach. For the simulation, we selected five well known allocation methods and applied them on real life data, obtained from a coalition of fresh produce traders. By joining forces, the partners were able to reduce the total transportation cost by 16 %.

Firstly, we can conclude that significant differences might exist if the gain sharing is done on a short or a long term basis. This is due to the fact that in the long term the efficiency of individual transportations average out and the results are based on the average performance of the coalition. We recommend an allocation of the gains on the short term, as here the efficiency of the individual transportations is used, resulting in a more adequate approximation of the real costs. One exception here is the Shapley Value, that is not influenced by the problem of aggregation.

In stead of focussing on the concept of fairness, the coalition should be aware of the impact of an allocation method on the more global idea of horizontal co-operation. As every allocation method is based on certain partner and coalition characteristics, incentives are given when selecting a certain mechanism. It can be seen that a Volume-based allocation favours the growth of the partners, without questioning flexibility of the partners or efficiency of the transport. The Shapley value and ACAM on the other hand strive toward efficiency by means of marginal costs. In order to achieve stability, the parties can choose for the Nucleolus as it assures a solution in the centre of the core. However, no direct link to operational parameters or partner characteristics can be found. Therefore, the results might be hard to interpret. Finally, the fairness of the EPM can be questioned in heterogeneous co-operations.

This study also confirms that a more flexible attitude of the collaborating parties results in higher possible profits for the entire group. Still, it remains important to weigh the extra profits against the engagement of being flexible.

This specific co-operation between fresh produce traders is perceived as a success story for both the traders and the logistic service provider (LSP). Due to bundling the traders were able to reduce transportation costs significantly. The LSP on the other hand can use his vehicle capacity more efficiently.

The current literature on horizontal co-operation is rather scarce and remains on the surface. For further research we believe that it might be useful to study in more detail the interactive relationship between the partners behaviour, the operational solution at the level of the coalition and the gain sharing (or cost allocation) mechanism. The Venlo traders case study shows clearly that a flexible behaviour of the partners—allow a shift of one day in the transportation date—can result in a positive cost effect for the coalition. This flexible behaviour should therefore be encouraged by giving the right specific incentives by means of a well-chosen gain sharing or cost allocation mechanism.

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## References

Bahrami K (2002) Improving supply chain productivity through horizontal cooperation: the case of consumer good manufacturers. In: Seuring S, Goldbach M (eds) Cost management in supply chains. Physica-Verlag, Heidelberg, pp 213–232

Biermasz J (2012) Report on the legal framework for horizontal collaboration in the supply chain. Technical report, August 2012

Cruijssen F, Salomon M (2004) Empirical study: order sharing between transportation companies may result in cost reductions between 5 to 15 percent. Discussion paper 80, Tilburg University

Cruijssen F, Cools M, Dullaert W (2007) Horizontal cooperation in logistics: opportunities and impediments. Transp Res E Logist Transp Rev 46(3):22–39

Cruijssen F, van Amelsfort L, Biermasz J, Louws M (2014) Method and tool support for the pilot projects. Technical report, June 2014

Ergun O, Kuyzu G, Savelsbergh M (2007) Reducing truckload transportation costs through collaboration. Transp Sci 41(2):206–221

Communication from the Commission (2011) Guidelines on the applicability of Article 101 of the Treaty on the Functioning of the European Union to horizontal co-operation agreements. Off J Eur Union 1–72

Frisk M, Göthe-Lundgren M, Jörnsten K, Rönnqvist M (2010) Cost allocation in collaborative forest transportation. Eur J Oper Res 205(2):448–458

Hageback C, Segerstedt A (2004) The need for co-distribution in rural areas—a study of Pajala in Sweden. Int J Prod Econ 89(2):153–163

Initiative and Capgemini (2008) Future supply chain 2016. Technical report, Global Commerce Initiative and Capgemini

Le Blanc HM, Cruijssen F, Fleuren HA, De Koster MBM (2006) Factory gate pricing: an analysis of the Dutch retail distribution. Eur J Oper Res 174(3):1950–1967

Lu M, Liesa F (2013) European technology platform on logistics input for the first calls of the horizon 2020 (draft). Technical report, WINN—European Platform Driving KnoWledge to INNovations in Freight Logistics, October 2013

Palander T, Väätäinen J (2005) Impacts of interenterprise collaboration and backhauling on wood procurement in Finland. Scand J Forest Res 20(2):177–183

Schmeidler D (1969) The nucleolus of a characteristic function game. SIAM J Appl Math 17 (6):1163–1170

Shapley LS (1953) A value for n-person games. Ann Math Stud 28:307–317

Tijs SH, Driessen TSH (1986) Game theory and cost allocation problems. Manage Sci 32:1015–1028

Vanovermeire C, Vercruysse D, Sörensen K (2014) Analysis of different cost allocation methods in a collaborative transport setting. Int J Eng Manag Econ 4(2):132–150

Wiegmans B (2005) Evaluation of potentially successful barge innovations. Transp Rev 25 (5):573–589

# Scheduling Serial Locks: A Green Wave for Waterbound Logistics

**Jannes Verstichel and Greet Vanden Berghe**

**Abstract** The present chapter focuses on locks and their impact on (inland) waterbound logistics. Examples of lock systems are given, and the main characteristics of the serial lock scheduling problem discussed.

Locks are often scheduled manually and, despite constituting a complex combinatorial problem, academia has given little attention to optimizing lock operations. Two measures can be suggested to considerably improve the competitiveness of inland waterway transportation within the supply chain: increasing the scheduling horizon of locks and treating series of locks as a single system, instead of operating them individually. A decision support system for the ship placement problem is introduced. The system is analysed both from the algorithmic and operational side, and some implementation difficulties are highlighted. Transferring ships through a series of locks based on their requested time of arrival at a destination, has potential to generate a green wave for waterbound logistics.

## 1 Introduction

A continuously growing share of maritime transportation in the logistics chain puts increasing pressure on both ports and waterways. Ship handling times are being reduced; flexibility strained and punctuality stressed for transporters to maintain their market position. Many aspects of ship and container handling have been extensively researched (Stahlbock and Voß 2008). Locks, key components of inland waterways and tide independent ports, have received little attention in academia. In tide independent ports, locks constitute a buffer between tide dependent bodies of water and the docks, where a constant water level strongly simplifies

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the ship's (un)loading process. On inland waterways, locks control both the water level and the flow. They level differences in altitude, enabling barges to travel rivers and canals that otherwise would be too shallow or curved.

Lock scheduling constitutes a complex optimization problem. The vast number of ships entering and leaving the harbor or travelling on the inland waterway network must be assigned to lock chambers. Their exact position inside the locks should be determined, and the resulting lockages require scheduling. Ship handling times strongly increase when a lock is not operated optimally. The lock's incapacity to transfer a ship in time may induce tardiness at the terminal. Consequently, inefficient lock operations increase the ship total time in port and disturb terminal operations. Similarly, inland waterways aim at reducing waiting times at the locks in order to increase the share of inland waterways in multimodal transportation[1] (European Commission 2009, 2011) and strengthen its position as a competitor for road transportation. Inland navigation is a most promising transportation mode in the multimodal chain, given its environmentally friendly nature and the excess capacity of the existing network (Caris et al. 2014).

In Western Europe, the vast network of inland waterways plays a crucial role in hinterland access of major sea ports (Notteboom and Rodrigue 2005). The Port of Antwerp, for example, transports 39 % of the goods to and from the hinterland by barges. The rapidly growing segment of container transportation aims at increasing the barge transportation share from the current 36 % to 42 % by 2030 (Port of Antwerp 2014). The recent growth in barge traffic will soon turn inland locks into major bottlenecks with unpredictable service times, thus limiting the inland waterway transportation's long term viability.

Against the backdrop sketched at large, various options to reduce the waiting times at locks and overcome the main downside of waterbound transportation are explored. The development and practical implementation of a decision support tool for placing ships in lock chambers is discussed, showing the potential of decision support systems for (inland) waterbound transportation, but also highlighting practical issues. Waterbound transportation could well gain a significant boost in interest from industry, and become a competitive alternative for road and rail transportation, not only by reducing travel time but also by offering accurate estimates of the expected traveltime for each ship.

## 2 Examples of Locks

The large and well-connected network of inland waterways in Belgium provides ample applications of serial locks. The Albertkanaal is one example of an important Belgian waterway, connecting the ports of Antwerp and Liège. Numerous industrial

[1] Multimodal transportation is the combination of multiple transportation modes in a single transportation chain without container changes for the goods.

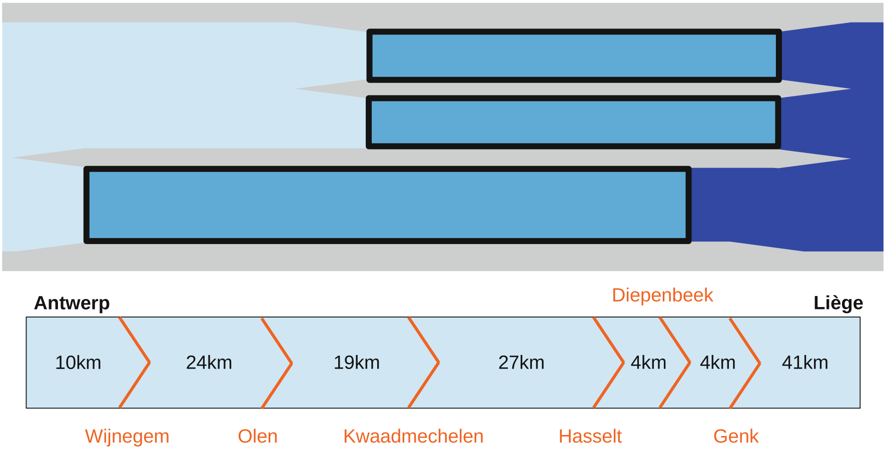


**Fig. 1** A schematic *top-view* of a single lock (*top*); length of the reaches of the series of locks on the Albertkanaal (*bottom*)

activities have emerged on its banks, with over 37 Million Tonnes Equivalent (MTE) of cargo processed in 2012 (nv De Scheepvaart 2012). Six triple-chamber locks overcome the height difference of 56 m between Antwerp and Liège. Each lock consists of two identical small chambers and a single large chamber, all of which can be operated independently. The locks handle a height difference between 5.7 m and 14 m. Figure 1 shows a top-view schematic of a lock, a graphical representation of the series of locks and the length of their reaches. Recent spells of drought combined with increasing barge traffic intensify the need for improvement of lock operations on the Albertkanaal. A significant reduction of the number of lockage operations (i.e. water usage) and the ships' waiting and travel times are the key solutions in such an operation.

The Strépy-Thieu boat lift on the Canal du Centre is yet another example. The elevator is the largest in the world, with a height difference between the upstream and downstream side of 73 m. The lock consists of two independent and watertight mobile cages (chambers) that are pulled up or lowered by a combination of counter balances and electrical motors (Walloon Government 2013b). The boat lift differs completely from regular locks, where the water level inside the chamber is changed instead of the chamber (and its contents). The Strépy-Thieu boat lift has led to a large boost of maritime traffic on the Canal du Centre, quadrupling the transported cargo from 0.2 MTE on the old lock system in 2001 to 0.8 MTE in 2003 when the lift became fully operational. It transported roughly 1.1 MTE in 2011 (Walloon Government 2013a).

The Port of Antwerp is the best example of ports behind locks. It is one of the largest ports in Europe, and processed more than 180 MTE of cargo and 70,000 ships in 2012, an average of almost 200 ships per day (Port of Antwerp 2012). The port is situated on the river Scheldt with tidal differences averaging five meters and acts as a major hub for both inland and intercontinental cargo traffic. A constant water level is ensured by locks separating the port's docks from the main water way.

The locks' chamber sizes range from 180 m × 22 m to 500 m × 68 m. In the Netherlands, the locks of Terneuzen enable seagoing vessels to enter the ports of Terneuzen en Ghent, and the construction of a new lock is underway with works starting in 2015. The Port of Le Havre (France) is yet another example of a port that is partially located behind locks.

Locks are also quite common in other European countries like Germany, Great Britain and Austria. Outside Europe, the Three Gorges and Gezhouba Dams in China, the *Upper Mississippi River* (UMR) and the Welland canal in North America are well known examples of serial inland locks. The most famous lock system, however, is probably the one situated on the Panama Canal, where a set of new, highly water-efficient locks is scheduled to be taken into action by the beginning of 2016 (Panama 2014).

## 3 Serial Lock Scheduling

The major components of (serial) lock scheduling are visualised in Fig. 2. The figure depicts a series of (multi chamber) locks transferring several ships.

The (serial) lock scheduling problem (LSP) denotes a computationally hard optimization problem. Ships constitute a first important part of the (serial) lock scheduling problem. They are defined by their length, width, draft, speed limitations, origin lock, and destination lock. The lock of origin is the first lock a ship has to traverse on its journey towards its destination, while the destination lock is the last lock the ship passes before ending its trip. Not necessarily a ship's origin and destination lock are the first and last locks on a given waterway. Ships may load and unload cargo in terminals along the banks of the rivers or enter/leave a waterway via one of its tributaries. A ship has an arrival time at each lock, determined by the moment it calls in at the lock. Contradicting this current practice, it would be more interesting for a ship to have a requested time of arrival (RTA) at its destination.

A second component of the LSP considers locks, which consist of at least one chamber in which ships can be transferred from one water level to another. Each

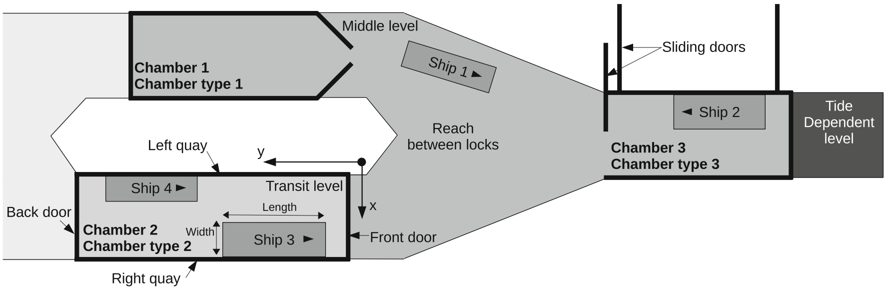


**Fig. 2** Representation of two serial chamber locks and important lock scheduling terminology

chamber is defined by its length(s), width, draft, minimum lockage time and safety distance constraints. It should be noted that a chamber may have several lengths when it has multiple doors at each side (Chamber 3 in Fig. 2). This is common practice for locks separating tide-dependent and tide-independent bodies of water. The locks are connected via reaches,[2] on which certain actions, such as overtaking or meeting (ships crossing each other), may be forbidden. When more than one chamber is available, the chambers can be paired (i.e. operated together) or operated independently. While some multi-chamber locks consist of several identical chambers, others have chambers with different dimensions and properties. The size of the chamber and certain safety regulations determine whether one or more vessels can be transferred in a single lockage operation. Processing a ship in a lock may thus require up to three decisions, each with a significant impact on the quality of service: selecting the chamber that will transfer the ship, determining a position for the ship in the chamber and setting a starting time for the lockage operation.

Several objectives for the lock scheduling problem have been studied. One is the minimization of the lock's water usage, often modelled as the total number of lockages required to transfer all ships (Verstichel et al. 2014a; Verstichel and Vanden Berghe 2009). While applying this objective results in a water efficient schedule, the resulting waiting times for the ships can be high, especially when the inter-arrival times between ships are long. Minimizing the ship's waiting time (Smith et al. 2011) or tardiness might therefore be taken into consideration. While there can be many ways to define a ship's waiting time, the assumption here is that a ship has an expected time of arrival (ETA) at the lock. The waiting time is then defined as the difference between the ship's ETA and the starting time of the lockage that transfers the ship. Minimizing a ship's tardiness is based on the requested time of arrival (RTA) at destination, or the equivalent requested time of completion at a ship's destination lock (RTC). The tardiness is defined as the difference between a ship's RTC and the completion time of the lockage transferring the ship. Fair schedules may be obtained by considering both a (weighted) average of the ship's waiting time/tardiness and the maximum value over all ships (Verstichel et al. 2014b). Indeed, a schedule with a low average waiting time might contain one or more large peaks: most ships have a small waiting time at the cost of a few ships waiting for a very long time. While including the maximum waiting time will temper the peaks to some extent, applying the squared waiting time as an objective has also proved to be most effective when targeting minimal peaks (Fleszar and Hindi 2002). A flow time objective aims at minimizing the time a ship spends traversing a series of locks. A ship's flow time is defined by the difference between its arrival at the first lock, and the completion time of the lockage that transfers the ship at its destination lock. When ships have an RTC, they may sail at unnecessary high speeds arriving long before their RTC and having consumed far more fuel than necessary. Fuel consumption minimization

[2] Reaches are the stretches of waterway between two locks.

(or minimization of the emission of $CO_2$ and other pollutants) may therefore also be an objective worth considering.

While this chapter focuses on (serial) locks with (parallel) chambers capable of transferring at least one ship in a single lockage operation, the methodologies presented can be easily extended to several other lock configurations (e.g. staircase locks[3] or boat lifts). One notable exception is the series of 600-foot locks on the Upper Mississippi River (UMR). These locks are located between two 1200-foot locks and constitute a traffic bottleneck. Large barge tows have to be decoupled and transferred in consecutive lockage operations in the same direction, requiring more than three times the time of a single lockage operation (Smith and Nauss 2010; Smith et al. 2009).

## 4 Positioning Ships in Locks

In an effort to create a green wave for waterbound logistics, the first part of the lock scheduling problem to take into serious consideration is the ship placement problem (Verstichel et al. 2014a). Given an ordered list of ships, the ship placement problem aims at minimising the number of lockages needed to place all ships, subject to a number of placement constraints. It requires placing as many as possible of the waiting and arriving ships in a chamber without violating safety and mooring constraints. Although difficult to disentangle, especially when several ships are waiting at the lock, the ship placement problem is oftentimes addressed manually by lock operators. Finding the right solution may require several minutes, making it hard for lock operators to plan ahead, compare scenarios, or even, respond to unexpected changes.

When a ship calls in at a lock and provides an ETA, the lock master could search the first possible lockage the ship will fit and provide an estimate of its processing time. This would enable the ship to alter its speed: increasing to catch an earlier lockage; decreasing to save fuel and arrive just in time for lockage. The cumbersome manual ship placement process does not allow lock operators to provide such estimates. Therefore, ships often sail at full speed to the lock to find out, upon arrival, that some waiting time is required. At locks with different parallel chambers, a lock master could solve the ship placement problem repeatedly in an effort to match the best chamber with a given set of ships. Such practice could, for instance, reduce the wasted space in the chamber (and thus water usage), or reduce waiting times by executing a turnback operation on a chamber, after having ensured however, that a sufficient number of waiting ships can be transferred in this chamber. Unexpected changes such as ships calling in at the lock at the very last moment, or suddenly deciding not to join the lockage, put pressure on the lock

[3] Staircase locks have several chambers located directly behind each other such that the downstream door of one chamber also acts as the upstream door of the next chamber (and vice versa).

operator. He or she has to decide quickly if the new ship can be added to a scheduled lockage, or if the cancelled ship freed up enough space to allow a waiting ship to enter the lockage after all. While this is easy when sufficient free space is available (e.g. the cancelled ship is larger than the waiting ship), (partial) reconfiguration of the assigned ship positions is often needed. The latter a significant effort of the lock operator.

The above mentioned examples clearly show the potential of a decision support and optimization tool for assisting the lock operators. The ship placement problem is therefore investigated in further detail in the following sections.

### *4.1 A Ship Placement Model*

The ship placement problem is a variant of the well known two dimensional rectangular single bin size bin packing problem (2D rectangular SBSBPP) (Wäscher et al. 2007). There, a set of rectangular items (ships) are to be positioned inside as few rectangular bins (lockages) as possible, not allowing for rotation of the items present. It is, however, possible to consider a single lockage at a time without loss of generality (Verstichel et al. 2014a). The present section investigates the single lockage version of the ship placement problem. It should be noted that a translation to rectangular bin packing requires the assumption of rectangular-shaped ships. The exact shape of the ships is often not available to lock operators, and therefore this simplification from real ship shapes to rectangles is common practice. Modelling each ship as a single rectangle makes little or no difference, except when the lock transfers *barge tows*.[4] These tows may have some free space in their configuration that can be used by another ship to position itself during the lockage operation. Figure 3 shows an example of a barge tow (dark grey) with a free space, and how this space can be used to place a ship (light grey). Modelling each tow as a fixed configuration of rectangles can supersede the resulting inconvenience.

Figure 4 visualises violations of the three standard constraints of two dimensional bin packing. Figure 4a shows a violation of the overlap constraint,

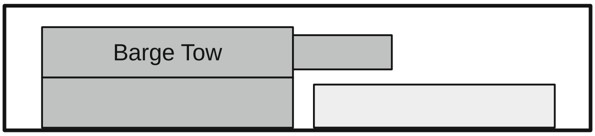


**Fig. 3** A visual representation of a barge tow (*dark grey*) and how an additional ship (*light grey*) can be added to the lockage

[4] Barge tows are a number of (unpowered) barges that are bound to a powered barge/tow, and act as a single unit.

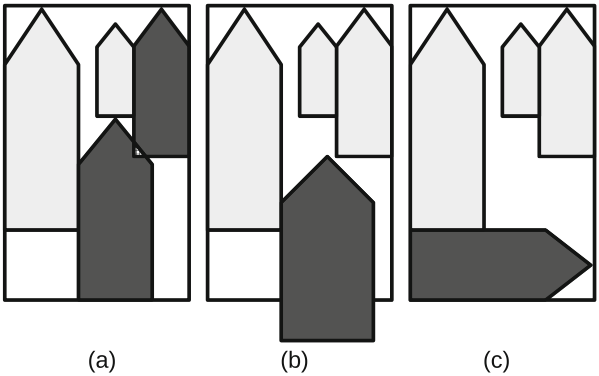


**Fig. 4** A visual representation of the standard two dimensional bin packing constraints (*Light grey*: ship placed in a correct way; *Dark grey*: ship violates a mooring constraint)

prohibiting two ships to share the same space in the chamber. As the doors need to close before the lockage operation can start, all ships must be inside the chamber (Fig. 4b). Rotating a ship is prohibited for several reasons, including safety and manoeuvring time (Fig. 4c).

A number of additional constraints must be taken into account when modelling the ship placement problem. First, a sequence constraint stipulates that the ships need to be processed in a first-come-first-served (FCFS) way with respect to their serial number in the ship list. This means that if Ship 5 in the list cannot be placed in the lockage, whereas Ship 6 would fit in the remaining space, it is not allowed to add Ship 6 to the lockage.

A second addition considers the mooring constraints: each ship must be moored either alongside the quay, or alongside another ship. Geometrically, Ship *a* is said to be moored to Ship *b*, when Ship *a* is adjacent to Ship *b* over its entire length. This constraint implies that each ship will be connected to the quay through larger ships, or through ships of equal size. The width of a ship does not affect the evaluation of the mooring constraint. Examples of solutions that do not satisfy this mooring constraint are visualised in Fig. 5a–c, where the dark grey ship is respectively too long, not moored over its entire length, and not moored at all. These mooring constraints are enforced to ensure safety during lockage. The water level in the chamber changes rapidly, resulting in strong currents. These currents could cause unmoored ships to collide with other ships, the quay, or even worse: one of the doors, potentially taking the chamber out of service for a period of time while the damaged door is being repaired or replaced.

Although the above described mooring constraints are sufficient in most cases where only inland ships are considered, some additional mooring/safety constraints may be required in other settings. Oftentimes, seagoing vessels can only be moored to the quay. In the case of mixed seagoing/inland traffic, inland ships are normally not allowed to moor to sea ships. Furthermore, ships may not be allowed to moor to each other when the difference in hull height above the water is too large (for example between fully loaded and empty ships). Figure 5d visualises these additional restrictions, which can be modelled as group-mooring constraints that only allow mooring to ships of a certain type.

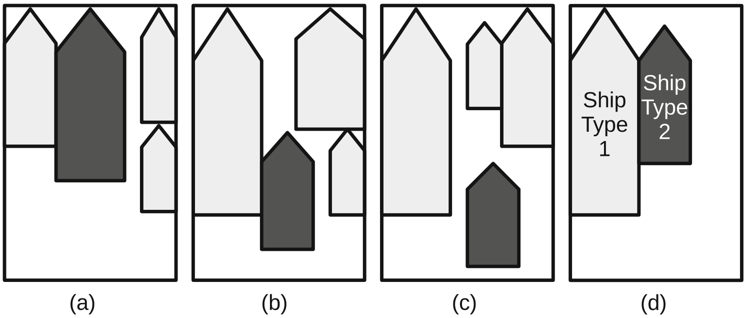


**Fig. 5** A visual representation of the mooring constraints of the ship placement problem (*Light grey*: ship placed in a correct way; *Dark grey*: ship violates a mooring constraint)

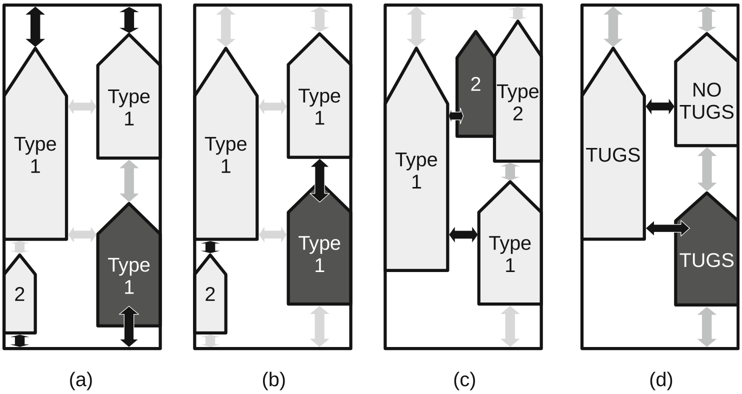


**Fig. 6** A visual representation of the safety distance constraints of the ship placement problem (*Light grey*: ship placed in a correct way; *Dark grey*: ship violates a mooring constraint)

A last set of additional constraints deals with the typical safety distances of the ship placement problem. Some 'room' must be given to ships, allowing for corrections to prevent collisions while manoeuvring in and out of the chamber, and in case of a minor accident during the lockage operations. While these safety distances can be considered equal for all ship tuples in an inland setting, sea ports call for a traffic dependent approach. The safety distance constraints for different ship tuples are visualised in Fig. 6. Based on the type of ship and its dimensions, a minimum lateral and longitudinal safety distance can be calculated. Fig. 6a shows (a violation of) the minimum safety distances that must be maintained between ships and the doors of the chamber. These are implied both for safety (i.e. avoid collisions with the doors) and practical reasons (position of the mooring poles to which the ship can attach). The minimum longitudinal and lateral distances between ships is visualised in Fig. 6b and c respectively. When ships use tugboats, the lateral safety distance must also be sufficiently large to allow for the tugboats to sail between the ships when leaving the chamber before the lockage operation starts (Fig. 6d).

### 4.2 An Optimization Approach to the Ship Placement Problem

Two characteristics are key to any decision support tool: response time and solution quality. When placing ships in chambers, the response times of the system should be small to obtain maximum flexibility with the system (compare different scenarios, react to changes). However, there is no use in providing solutions in a few milliseconds when the operator requires several minutes to validate the safety compliance of the presented solution. Solutions that can be quickly evaluated are indeed of utmost importance: the lock operators keep responsibility for the safety compliance of all lockages.

Although high-performance approaches exist for the 2D rectangular SBSBPP, the current single-lockage premises makes it worthwhile to explore approaches to the rectangular strip packing problem instead. While solving the bin packing problem entails minimising the number of bins (lockages) required to place all items (ships), strip packing tries to minimise the total length required to place all items (ships) on a single strip (chamber). The latter indeed closely resembles the objective of the ship placement problem. Owing to the first-come-first-served constraints, the ship placement problem can be tackled by adding one ship at a time to the corresponding strip packing problem. The procedure starts by solving the strip packing problem for the first ship in the ship list. The next ship in the list is added and a new strip packing instance is solved, until the required strip length exceeds the chamber length. This process is visualised in Fig. 7. The top part of the figure shows the ship placement problem, the bottom part denotes how a solution (d) is generated by iteratively solving a strip packing problem.

Several metaheuristics achieve excellent results on the rectangular strip packing problem. The bar was set in 2008 by a reactive greedy randomized adaptive search procedure (GRASP) approach (Alvarez-Valdes et al. 2008) and the SVC (SubKP) heuristic (Belov et al. 2008), both obtaining several of the best results in the literature. An iterative doubling binary search (IDBS) method (Wei et al. 2011) further improved these results. Although obtaining state of the art results, these three metaheuristics have one common downside: they require the implementation of very complex algorithms. The search for straightforward metaheuristics obtaining comparable or even better results quickly gained interest. The intelligent search algorithm (ISA) (Leung et al. 2011) combines simulated annealing, a constructive heuristic and a simple scoring rule. The simple randomized algorithm (Yang et al. 2013) uses many of the same ingredients but applies a random acceptance criterion instead of simulated annealing, and uses an improved scoring rule, obtaining slightly better results. These metaheuristics are all based on the same principle: generating different input sequences/parameters for existing

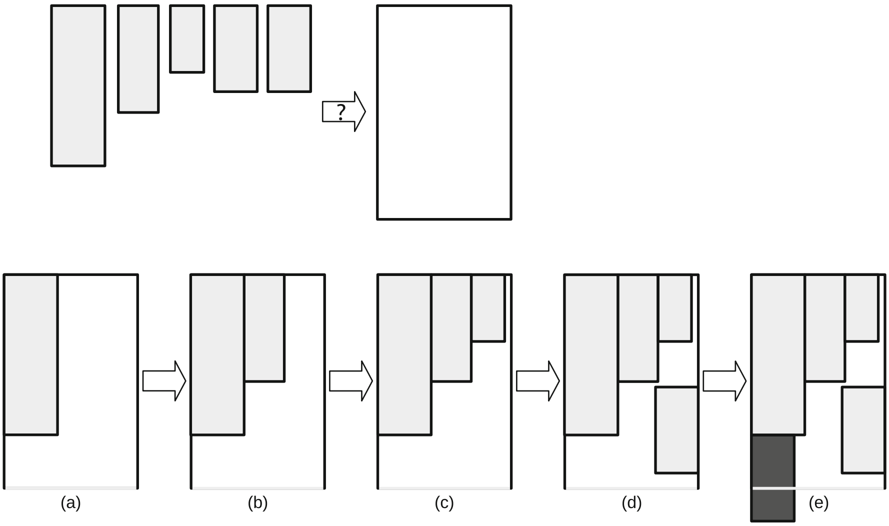


**Fig. 7** An example of an iterative procedure to solving the ship placement problem, based on the corresponding strip packing problem (*Light grey*: ship placed in a correct way; *Dark grey*: ship is placed outside the chamber's boundaries)

(constructive) heuristics in order to improve their results. A simulated annealing bottom left fill hybridization of the best fit algorithm (Burke et al. 2009) combines this paradigm with the two most popular constructive strip packing heuristics: the bottom left (fill) heuristic (Baker et al. 1980; Chazelle 1983) and the best fit heuristic (Burke et al. 2004). The latter is a very straightforward heuristic that outperforms the bottom left (fill) heuristic on all benchmarks with more than 50 items and the majority of smaller instances, and has a $O(n \log n)$ time complexity implementation (Imahori and Yagiura 2010). The three-way best fit heuristic (Verstichel et al. 2013) combines the best fit heuristic's speed with an increasing solution quality when different input sequences are applied. Instead of generating a large number of item sequences, the authors generate a limited number of distinctly different sequences, sampling the search space as efficiently as possible. The heuristic obtains significantly better results than the original best fit heuristic in comparable computation times. It serves as the basis of the (multi-order) best-fit heuristic for the ship placement problem (Verstichel et al. 2014a). The heuristic prioritizes the placement of ships based on a decreasing width/length/size order. As a consequence, solutions constructed by this heuristic show a tendency to group ships of similar size, mimicking (to so some extent) the behaviour of lock operators who group ships of similar size together in a single block in an effort to simplify the problem.

Adapting the best fit heuristic to a heuristic for the ship placement problem requires several modifications. Fortunately, these modifications are easy to incorporate, owing to the heuristic's structural make-up. Figure 8 illustrates how the best fit heuristic for the ship placement works. The figure visualizes a single best fit

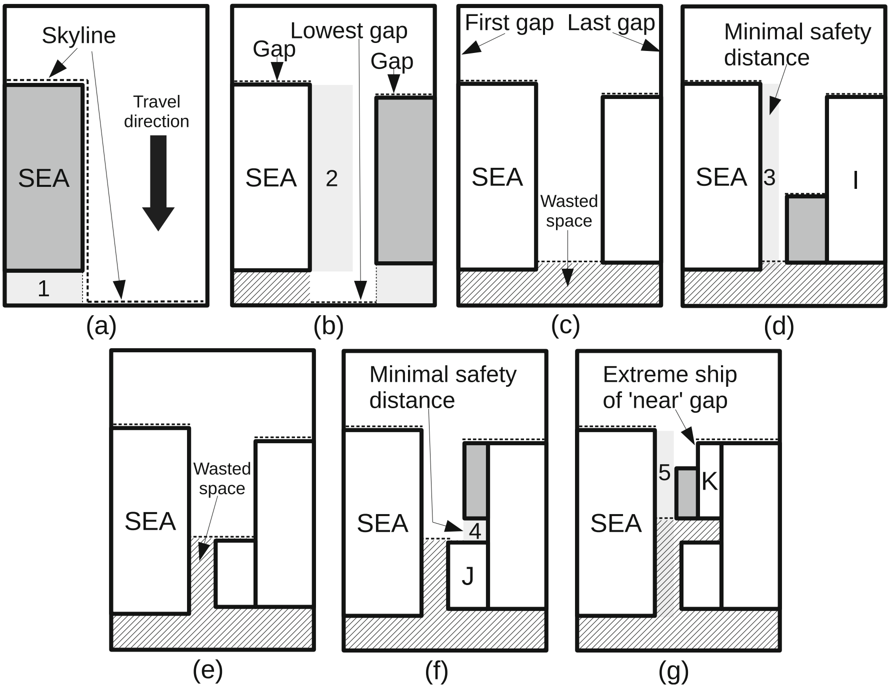


**Fig. 8** Representation of the best fit heuristic for the ship placement problem, based on a single best-fit iteration with a decreasing width ordering and a rightmost placement strategy. Newly placed ships are *dark grey*, safety distances are *light grey*, gaps are represented by *dashed lines*, and wasted space is *hatched*

solution construction, using a decreasing width ordering. The heuristic consists of three core components: a ship ordering method, a ship placement policy and an array of gaps. The ordering method determines the placement priority of each ship. The placement policy determines the preferred mooring side (left or right). The gaps form a skyline determining the free space in the chamber (Fig. 8a), thereby removing the need for costly overlap checks. A ship is always placed in the lowest gap in the skyline (Fig. 8b). If at any time during the search none of the remaining ships fit this lowest gap, it is filled up to the level of the least-protruding gap-defining-ship and stored as wasted space (Fig. 8e). Safety distances (Fig. 8b) or mooring constraints (Fig. 8c) can also induce wasted space. Contrary to the strip packing problem, checking the gap's width does not suffice to guarantee a feasible position for the new ship. The gap's neighbouring ships also determine whether or not a ship can 'fill' it: the candidate ship must be allowed to moor to either the left or the right neighbouring ship. Therefore, when placing a ship in the chamber, it is stored as part of a gap, with the last ship added to each gap called its 'extreme ship' (Ship SEA in Fig. 8a, ship K in Fig. 8g). Adding ship information to the gaps in this way enables a straightforward evaluation of the mooring and safety distance constraints. In Fig. 8g, for example, it suffices to check the properties of the extreme

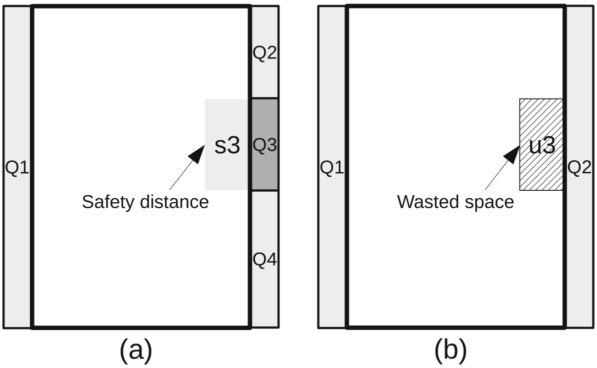


**Fig. 9** Different ways to model unavailabilities in the chamber. Subfigure (**a**) shows how multiple quay ships enable introducing unavailabilities of the quays (Safety distance 's3' of quay ships 'Q3'). Subfigure (**b**) shows the same result can be obtained by introducing wasted space ('u3') in the empty chamber

ship (K) of the 'near' gap to evaluate the mooring constraints for the dark grey ship. Checking the extreme ship (SEA) of the 'far' gap, enables computing lateral safety distance '5' in Fig. 8g. Evaluation of the longitudinal safety distance '4' is possible by checking the properties of the ship(s) in the lowest gap (Ship J in Fig. 8f). This system also facilitates modelling the chamber's quays as extreme ships of the first and last gap (Figs. 8c and 9). The chamber's front door is added as a ship in the initial lowest gap, enabling the computation of safety distance '1' in Fig. 8a.

While incorporating this heuristic in a decision support tool for the Port of Antwerp, several additional operational restrictions arose. Mooring side restrictions based on the properties of a ship (e.g. the bow thruster) were added by applying a different type for the quay ships in the first and the last gap. Safety regulations concerning the mooring operation of seagoing vessels in case of medium to strong winds were added with a small adaptation of the placement policies. Unavailabilities on one of the quays due to maintenance, repairs or quayside renovations were modelled by either introducing multiple quay ships (Fig. 9a) or by adding wasted space to the empty chamber (Fig. 9b). The latter requires computation of an overlap check when placing a ship in the chamber. Owing to the limited number of unavailabilities that can be present in a chamber at any given time, this does not have a negative influence on the computation time. These approaches for unavailabilites can also be applied when one or more ships are already moored in the chamber, and the lock master wants to add more ships. This is very convenient when transferring a mix of large seagoing vessels (which require a long time to enter the chamber and moor) and barges (which may call in at the lock till up to a few minutes before the lockage operation starts). Modelling the seagoing vessels as unavailabilites allows the lock master to determine the positions of the barges 'just in time'. A thorough analysis of the solutions produced by this modified multi-order best-fit heuristic at the Port of Antwerp showed that the heuristic clearly constructs the same solutions a lock operator would propose. However, an important difference should be strongly underlined: the heuristic requires a few milliseconds; the lock operator several minutes.

Gaining the trust of users is of prime importance when introducing (complex) decision support tools. The ship placement problem comes in handy as it is easy to visualize and validate solutions. The success of such tools also depends heavily on the data management systems at the locks and on the accuracy of parameters, such as minimal safety distances and mooring preferences (Caris et al. 2013). Some lock systems are connected to (international) ship databases, automatically retrieving all important ship characteristics when a ship calls in; others still require the lock operator to manually enter all the data. In the latter case, a decision support tool must be accompanied by the introduction of improved data management systems. When no accurate data is available, it is impossible to distill common practices from past lockages; neither can the safety distances maintained at a lock be determined. The latter proved to be very important during the development of the decision support tool. Significant differences between the provided standard safety distances and the minimum safety distances maintained by lock operators during peak traffic were detected. Finally, gathering accurate information about ship travel and processing times is of paramount importance when seeking to extend the decision support system's scope towards scheduling lockage operations.

## 5 Scheduling Lockage Operations

Scheduling lockage operations for a single lock strongly resembles the well known machine scheduling problem. A lockage may not start before all the ships it transfers have arrived at the lock and have had sufficient time to approach/enter the chamber. Lockages can be processed by any of the identical parallel chambers at a lock, but a lockage scheduled for a large chamber cannot be executed on a chamber with smaller dimensions, as this would lead to ship placement violations. When two lockages are processed in the same direction on the same chamber, an empty lockage in the opposite direction must be organized in between, resulting in a setup time between the two lockages. Furthermore, when dealing with large seagoing vessels, ship dependent approach, mooring, unmooring, and departure times must be considered: large vessels require some time to manoeuvre to their position, (dis)engage tugboats, etc. Substituting chamber by machine and lockage by job, reveals that lockage scheduling maps to the parallel machine scheduling problem with release dates, machine eligibility constraints and sequence dependent setup times (Verstichel et al. 2014b).

Optimizing the operations of each individual lock will, however, not suffice to create a good flow of the ships in the system. Research has shown interdependencies between serial locks on inland waterways, especially when lock utilization is high, and the reaches are short (Martinelli and Schonfeld 1995). Scheduling a series of locks as a single system is therefore of utmost importance to maximize efficiency under the pressure of the continuously growing maritime transportation. It will, however, add significant complexity to the problem. Ships can enter or leave the system between locks, at terminals or tributaries. As a result, the schedule at one lock may not be reusable at the next, and different ship placement problems may be encountered at each lock. The sailing speed may also differ among ships. Ships

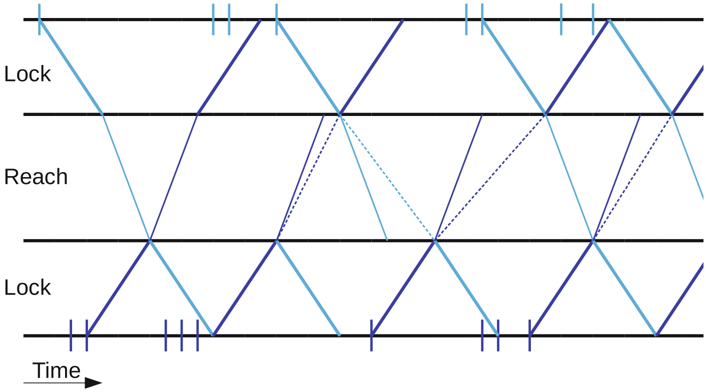


**Fig. 10** Visualization of a schedule for two serial locks. Ship arrivals at the locks (*top* and *bottom*) are depicted by *vertical dashes*. The *long horizontal lines* represent the entrance and exit of each lock. The *thick angled lines* visualise lockage operations, the *thin* ones ships sailing from one lock to another. The *dashed lines* show alternative sailing speeds minimizing fuel consumption

transferred together at one lock may not arrive close enough to each other to be transferred together in the next one. The bidirectional nature of the traffic is, however, even more important. There is a flow of upstream bound ships, and one of downstream bound ships. These flows cross each other at different moments in time at each lock, making the synchronization of both streams for a maximal throughput and minimal tardiness/waiting time a difficult task. Figure 10 visualizes a possible schedule for a series of two locks. Ship arrivals at the locks (top and bottom) are depicted by vertical dashes. The long horizontal lines represent the entrance and exit of each lock. The thick angled lines visualise lockage operations, the thin ones ships sailing from one lock to another. The dashed lines show alternative sailing speeds minimizing fuel consumption. The schedule illustrates how at each lock different upstream and downstream bound ships meet each other, making it hard to reuse the schedule of one lock at another one without significantly increasing the waiting times, even when no ships enter or leave the system between the first and the last lock.

Scheduling lockage operations on serial locks is related to the bidirectional flowshop problem with parallel machines and batch operations. The set of ships transferred in a lockage operation can be different at each lock. Therefore, lockages no longer correspond to jobs. Jobs need to be mapped to ships, and lockages to batches that may have a different composition at each machine. Solutions for this problem quickly become intractable, and research on interdependent serial locks has, until now, focused on simulation models (Dai and Schonfeld 1998; Martinelli et al. 1993; Smith et al. 2009, 2011). An interesting research direction would be to apply existing and new optimization algorithms for ship placement and lockage scheduling in advanced simulation models. There are several benefits to such an approach. First and foremost, visualizing a complex schedule via simulation makes it easy to interpret and detect interesting parts or possible anomalies. Running simulations on historical data also enables quick detection of errors in provided parameters. For example, errors with respect to minimum setup times, manoeuvre times and sailing speed may deteriorate the accuracy of the decision support tool in practice. The absence of accurate data on the inland waterway transportation chain, or the absence of data in its entirety, is still one of the main difficulties when trying to bring solution methods for waterbound transportation to practice (Caris et al. 2013, 2014). Even though several steps have been taken to gather and standardize data (COMCIS 2013; European Commission 2013) and systems like RIS (River Information Services) have increased safety and efficiency on inland waterways, applications focusing on the optimization of the logistics process and modal integration are still missing (European Commission 2014). It will take significant efforts of researchers, operators, terminal operators, software companies and policy makers to enable accurate data capturing and sharing in order to accommodate the development and application of decision support systems for this complex problem.

When accurate data is available, however, the possible efficiency gains for (inland) waterbound transportation are legion. At present, barges often have no other option but sailing at full speed between locks, in the hope of making their deadline at their destination. Upon arrival at the lock, however, they face queues and have to wait a considerable time before being processed. When scheduling the series of locks as a single system, the barge operators could send a itinerary request to the lock operators beforehand, stating their route (origin and destination lock) and the requested time of completion at the destination lock. When a sufficiently large percentage of the barges uses this system, a schedule can be computed in advance where all ships arrive close to their deadline. Furthermore, each ship can be provided a timetable with their assigned time of arrival at each lock, enabling them to optimize their sailing speed in each reach, saving fuel and reducing greenhouse gas emissions. This is visualized by the dashed lines in Fig. 10. By scheduling the vessels that do not participate in the system of pre-notification in the slack space in the schedule (i.e. when transferring these ships does not disturb the timetable for the vessels that provided their trajectory beforehand), a strong incentive is created for barge operators and other stakeholders to join the system.

## 6 Conclusion

The lock scheduling problem was introduced, and its relevance to the supply chain of the future explained. A careful analysis of the different challenges encountered when scheduling locks has shown some interesting avenues for increasing lock efficiency in real life applications. The implementation of decision support and optimization systems for inland waterbound transportation suffers dramatically from the lack of accurate data, especially ship travel times and requested arrival times at the destination. Gradually introducing decision support systems for parts of the waterbound logistics chain can help sanitize and expand the available data, enabling the introduction of optimization tools for increasingly complex problems.

Significant improvements in scheduling horizon, disruption management and peak traffic handling can be obtained by introducing decision support and optimization tools for placing ships in chambers. At the same time, the trust of the users is gained, as it is easy to interpret and validate proposed solutions to the easy to visualise ship placement problem. However, the strong interdependence between ship arrivals at serial locks restricts the impact of optimizing the lockage operations at a single lock on the overall performance of the system. Scheduling all the locks on a waterway, or even the network of waterways, as a single system will enable far greater improvements in waiting time and tardiness. It enables introducing a green wave for inland waterbound transportation, similar to the concept for road traffic, and allows ships to minimize fuel consumption by adjusting their speed to the schedule. Just in time arrivals at each lock are targeted. The influence of ships entering and leaving the system between locks, varying ship travel speed and synchronization of the upstream and downstream traffic renders the extension from single to serial locks far from trivial. The problem becomes even more complex when considering what happens after the ship leaves its destination lock. A barge may quickly traverse the lock system, only to start queuing at the terminal. Seagoing vessels might require assistance of tugboats to leave the lock and continue their journey, blocking the chamber and disrupting the lock's timetable when no tugboats are available. Needless to say that many more academic and practical challenges await in the search for efficient, green and flexible waterbound logistics as part of the supply chain of the future.

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## References

Alvarez-Valdes R, Parreno F, Tamarit J (2008) Reactive grasp for the strip-packing problem. Comput Oper Res 35(4):1065–1083

Baker B, Coffman E Jr, Rivest R (1980) Orthogonal packings in two dimensions. SIAM J Comput 9(4):846–855

Belov G, Scheithauer G, Mukhacheva EA (2008) One-dimensional heuristics adapted for two-dimensional rectangular strip packing. J Oper Res Soc 59(10):823–832(10)

Burke E, Kendall G, Whitwell G (2004) A new placement heuristic for the orthogonal stock-cutting problem. Oper Res 52:655–671

Burke E, Kendall G, Whitwell G (2009) A simulated annealing enhancement of the best-fit heuristic for the orthogonal stock-cutting problem. INFORMS J Comput 21(3):505–516

Caris A, Macharis C, Janssens GK (2013) Decision support in intermodal transport: a new research agenda. Comput Ind 64(2):105–112

Caris A, Limbourg S, Macharis C, van Lier T, Cools M (2014) Integration of inland waterway transport in the intermodal supply chain: a taxonomy of research challenges. J Transp Geogr 41:126–136
Chazelle B (1983) The bottomn-left bin-packing heuristic: an efficient implementation. IEEE Trans Comput C-32(8):697–707
COMCIS (2013) COMCIS FP7 project website. http://www.comcis.eu
Dai MD, Schonfeld P (1998) Metamodels for estimating waterway delays through series of queues. Transp Res B Methodol 32(1):1–19
European Commission (2009) Communication from the commission: a sustainable future for transport—towards an integrated, technology-led and user friendly systems. http://ec.europa.eu/transport/media/publications/doc/2009_future_of_transport_en.pdf
European Commission (2011) Transport white paper: roadmap to a single European transport area—towards a competitive and resource efficient transport system. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0144:FIN:EN:PDF
European Commission (2013) e-freight: a concrete step forward and the call for policy action. http://ec.europa.eu/transport/newsletters/2013/12-06/articles/e-freight_en.htm
European Commission (2014) Evaluation of RIS implementation for the period of 2006-2011, main report. http://ec.europa.eu/transport/modes/inland/studies/doc/2014-07-evaluation-of-ris-implementation-main-report.pdf
Fleszar K, Hindi KS (2002) New heuristics for one-dimensional bin-packing. Comput Oper Res 29 (7):821–839
Imahori S, Yagiura M (2010) The best-fit heuristic for the rectangular strip packing problem: an efficient implementation and the worst-case approximation ratio. Comput Oper Res 37 (2):325–333
Leung S, Zhang D, Sim K (2011) A two-stage intelligent search algorithm for the two-dimensional strip packing problem. Eur J Oper Res 215(1):57–69
Martinelli D, Schonfeld P (1995) Approximating delays at interdependent locks. J Waterw Port Coast Ocean Eng 121(6):300–307
Martinelli D, Dai MD, Schonfeld P, Antle G (1993) Methodology for planning efficient investments on inland waterways. Transp Res Rec 1383:49–57
Notteboom T, Rodrigue JP (2005) Port regionalization: towards a new phase in port development. Mar Policy Manage 32(3):297–313
nv De Scheepvaart (2012) Annual report 2012 (in Dutch). http://www.descheepvaart.be/uploads/scheepvaart/FILE_1DAC7D33-98D9-4971-978F-12C499037150.PDF
Panama Canal (2014) Panama canal updates Maersk line on expansion program. http://www.pancanal.com/eng/pr/press-releases/2014/08/20/pr519.html
Port of Antwerp (2012) Annual report 2012. http://www.portofantwerp.com/en/annual-report-2012
Port of Antwerp (2014) Instream: smart and efficient inland navigation. http://www.portofantwerp.com/sites/portofantwerp/files/POA-1473_Brochure_Instream_EN_Def.pdf
Smith L, Nauss R (2010) Investigating strategic alternatives for improving service in an inland waterway transportation system. Int J Strat Decis Sci 1:6281
Smith LD, Sweeney DC, Campbell JF (2009) Simulation of alternative approaches to relieving congestion at locks in a river transportation system. J Oper Res Soc 60(4):519–533
Smith L, Nauss RM, Mattfeld DC, Li J, Ehmke JF, Reindl M (2011) Scheduling operations at system choke points with sequence-dependent delays and processing times. Transp Res E Log Transp Rev doi: 10.1016/j.tre.2011.02.005. http://dx.doi.org/10.1016/j.tre.2011.02.005
Stahlbock R, Voß S (2008) Operations research at container terminals: a literature update. OR Spectr 30:1–52
Verstichel J, Vanden Berghe G (2009) A late acceptance algorithm for the lock scheduling problem. Logis Manage: 457–478. www.lm09.de
Verstichel J, De Causmaecker P, Vanden Berghe G (2013) An improved best fit heuristic for the orthogonal strip packing problem. Int Trans Oper Res 20:711–730

Verstichel J, De Causmaecker P, Spieksma FC, Vanden Berghe G (2014a) Exact and heuristic methods for placing ships in locks. Eur J Oper Res 235(2):387–398

Verstichel J, De Causmaecker P, Spieksma F, Vanden Berghe G (2014b) The generalized lock scheduling problem: an exact approach. Transp Res E: Log Transp Rev 65:16–34

Walloon Government (2013a) Full and summarized year reports 2003-2011 of the Wallonian inland waterways (in French). http://voies-hydrauliques.wallonie.be/opencms/opencms/fr/nav/navstat/docstat.html

Walloon Government (2013b) The Strépy-Thieu boat lift. http://services-techniques.met.wallonie.be/en/waterways/strepythieu_boat_lift/

Wäscher G, Haußner H, Schumann H (2007) An improved typology of cutting and packing problems. Eur J Oper Res 183:1109–1130

Wei L, Oon WC, Zhu W, Lim A (2011) A skyline heuristic for the 2D rectangular packing and strip packing problems. Eur J Oper Res 215(2):337–346

Yang S, Han S, Ye W (2013) A simple randomized algorithm for two-dimensional strip packing. Comput Oper Res 40(1):1–8

# Supply Chain Network Design: Tackling Regulations, Lead Time and Cost-Efficiency

**Susana Val, Adekunle Kehinde, Andrew Machado, and Carolina Ciprés**

**Abstract** The main objective of this chapter is to deepen in the entire supply chain of the oil and gas industry by searching the feasibility of a new hub in Africa. The methodology will follow several criteria related to location, stability, lead times, profitability and intelligent hub among others.

Solutions come from comparison between the current situation and the one proposed in the chapter in terms of estimated total cost. A sensitivity analysis has also been performed, focusing on what would happen in the event of 5, 10, 20 and 30 working days being lost due to strikes.

Derived from these results, the chapter provides a set of recommendations regarding to location of the hub, renting equipment, modal transport and benchmark. Results are focused in the industries' supply chains, especially those oriented to similar kinds of markets and looking for new opportunities in the African continent. The issue of customs and free trade zones is widely contemplated in the chapter and provides insights of feasible locations to establish future hubs.

## 1 Introduction

Companies are linked to upstream suppliers and downstream distributors through the whole supply chain by mean of materials, information and capital flow. The oil and natural gas industry is one of the world's largest industries. Its revenues are large, as are the costs of providing consumers with the energy they need. Among those costs are exploration and producing oil and natural gas, refining, distributing to consumer interfaces and marketing those refined products. The energy consumed today is brought by investments made years or even decades ago. This industry is divided into the 'upstream' and 'downstream' operations. Upstream involves exploring for oil and gas and extracting it safely. The downstream part of the industry is concerned with refining, distribution and sales.

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The largest volume products of the industry are fuel oil and gasoline (petrol). Petroleum (oil) is also the raw material for many chemical products, including pharmaceuticals, solvents, fertilizers, pesticides, and plastics. Petroleum is vital to many industries, and is of importance to the maintenance of industrial civilization in its current configuration, and thus is a critical concern for many nations. Oil accounts for a large percentage of the world's energy consumption, ranging from a low of 32 % for Europe and Asia, to a high of 53 % for the Middle East. The world consumes 30 billion barrels (4.8 $km^3$) of oil per year, with developed nations being the largest consumers.[1]

Advances in exploration and production have helped to locate and recover a supply of oil and natural gas from major reserves across the globe. But supply and demand are rarely concentrated in the same place. Transportation therefore is vital to ensuring the reliable and affordable flow for the daily life.

This market can benefit from maximizing supply chain efficiencies more than other market segments since the type of shipments made vary widely from gloves to pipes, valves, cranes, chemicals, cement, steel, and drilling rigs, just to mention a few (Chima 2007). Those supplies need to move even daily in large quantities for local, regional or international (offshore), which makes essential scheduling in advance. A delay in the delivering of tubes or pipes can result in high operational costs in comparison with traditional supply chains.

Improvements in the oil and gas supply chain also consider information technologies as typically used in traditional supply chains. Information sharing could lead to reducing total costs in the supply chain. To this end vertical integration is considered as a tool to facilitate information technology to the supply chain.

According to some research, there are companies from the oil and gas sector that may be able to share more information in a more effective way by the design of a cloud based on the exchange of planning information. This is the way to provide real time data with standardized formats. Companies such as OFS[2] use the cloud to better forecast their material resources for instance. This system seems to work better since some oil and gas companies are reluctant to share data.

There are some challenges affecting the supply chain; regulations and customs differ from one country to another, fluctuation of fuel prices and there is also a lack of track record (data from past 5 to 10 years, which makes very difficult to accurately predict future results). Besides, the key drivers behind a successful supply chain include quick point-to-point transfers, a solid operation on the ground and the knowledge of local collaborators. From the logistics prospective, oil and gas companies have some critical issues that can allow them or not continuing in the market. Those are the segmentation of customers according to the needs, the customization of the logistics network, demand variability amplification or bull-whip effect, partnerships with shippers, strategic sourcing, information systems and operational innovation among others (Chima 2007).

[1] http://en.wikipedia.org/wiki/Petroleum_industry

[2] Accenture. Supply Chain Improvements in Oil and Gas: Building an Operations Factory, 2013

Reliability is also a crucial factor in supply, both of quality and timing. For instance, if supplies are of poor quality, delivered late or cost more than was agreed, this fact can affect productivity and profitability. Besides, if production is delayed or faulty products need to be scrapped, this can reduce profits. Poor quality inputs could also affect the safety of the process.[3] The oil and gas industry has long been recognised as one of the most competitive fields of work. While numerous reserves are discovered in nearly all corners of the globe, they are still in various stages of development. For example, while operations in the Arabian Gulf are well-established and provide upwards of 15 million barrels of oil per day (Carroll 2013), countries in Africa are yet to fully realise their potential despite the huge reserves that exist in countries such as Angola and Nigeria.

This chapter will show the example of an oil and gas industry that is keen to explore the possibilities of expanding its operations in Africa and aims at discovering the feasibility of such a project by redesigning its supply chain.

The desire to create an efficient supply chain is an issue that keeps many a manager perturbed. Driven by increasingly competitive markets, the pressure on corporations to deliver higher value to their customers and shareholders has resulted in attempts to make supply chain management more fluid and complex than ever before (Ernst and Young 2011). As multinational corporations tap into the potential of emerging markets, most have realized that the conventional Northern hemisphere supply chain hubs[4] (Fig. 1), e.g. Rotterdam, California, Singapore and Shanghai, may not be sufficient as operations expand globally.

While there are some major bases in the southern hemisphere, e.g. Sao Paulo, Durban, it is obvious from looking at the diagram that the vast majority of transport still happens between ports in the northern hemisphere. This chapter explores the feasibility of setting up a supply base in South Africa and the benefits it might offer to international companies should they decide to expand their supply chain to include Sub-Saharan Africa.

## *1.1 Supply Chain Context of the Oil and Gas Industry in Africa*

Africa is endowed with vast amount of energy resources. A report by African Development Bank (AfDB) (2009) discussed how recent discoveries of oil and gas reserve in the continent have transformed the continent to a global player in oil production and resources extraction. According to PriceWaterhouseCooper's

[3] http://businesscasestudies.co.uk/opito/the-importance-of-sustainable-purchasing-and-supply/purchasing-and-supply-in-oil-and-gas.html#axzz3Swj5RkhJ

[4] The concept "hub" refers to a node where the main activities of the company are centralized. These hubs are chosen due to a certain parameters such as location, workload, transportation cost, distance O/D and customs regulations among others.

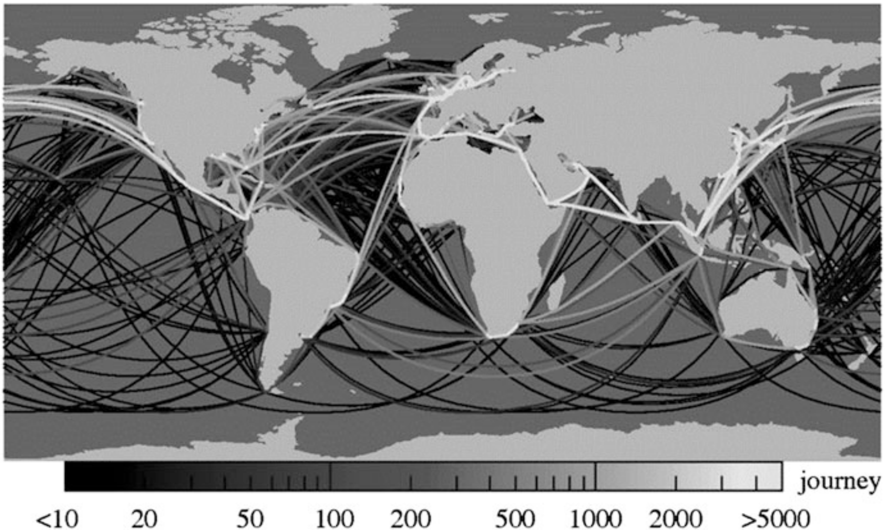


**Fig. 1** World ocean cargo transport route (At Waters Edge 2011)

(PwC) yearly report (2013), Africa holds about 8 % (132.4 trillion barrels) of the world's proven oil reserve and 7 % (513.2 Trillion cubic feet) of world's gas reserve. Data from U.S. Energy Information Administration (EIA) (2013) also shows that Africa's oil reserves have grown by more than 120 % in the past 30 years—from 57 billion barrels in 1980 to 127 billion barrels in 2013.

In addition, proven natural gas reserves have also grown by more than 140 % over this period—from 211 trillion cubic feet in 1980 to 514 trillion cubic feet in 2013. In 2012, Africa's oil production represented 11.2 % [10.042 million barrels per day (bpd)] of world's daily total oil supply; with a projected increase to 12 million bpd in 2020. The growth has been due to new oil and gas discoveries in countries like Tanzania, Mozambique, Ghana and South Africa; and capacity expansion in Africa's key oil producing countries such as Angola and Nigeria (KPMG Africa Limited 2013). As of 2012, there are 21 African countries with proven oil reserves and 24 African countries with proven natural gas reserves (US Energy Information Administration 2013).

KPMG's (2013) report highlighted how the recent increase in energy demand by emerging economies, such as India and China has led to a shift from dependence on Middle Eastern oil towards a greater focus on Africa. Figure 2 shows how China and India have gone from importing 10 % and 5 % of Africa's total oil output in 2007 to importing 14 % and 8 % of the same, respectively. This has changed not only Africa's oil export profile but has also brought investment opportunities to the continent, especially the Sub-Saharan region. This is mainly down to the increased economic power of the two Asia giants and bodes well for the future. Investment spending in African energy, especially in upstream exploration, is estimated to reach $1.25 trillion by 2030.

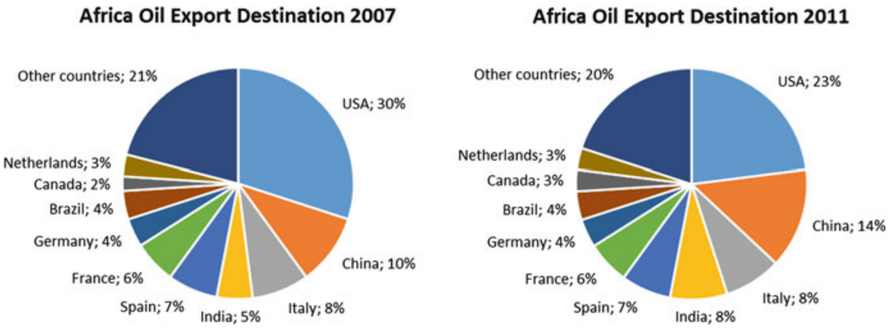


**Fig. 2** Africa oil export destination 2007 vs. 2011 (KPMG Africa Limited 2013)

## 2 Case Study: South Africa

South Africa is located at the southern tip of the continent of Africa with population of 48.6 million (Central Intelligence Agency 2013). The country is bordered by Namibia, Botswana, Zimbabwe, Swaziland and Lesotho; and the coastal regions are surrounded by the South Atlantic Ocean and Indian Ocean. South Africa has 11 official languages. Only 8 % of the population speaks English as a native language but it remains the mostly used medium in business, commerce, finance and government (The Economist 2013). This might be important for a multinational company when it comes to hiring qualified personnel.

The advantage of doing business in the African continent lies in the number of available shipping routes; the Cape of Good Hope has long been a point of transit for ships crossing the region that cannot or do not want to use the Suez Canal. Whether one wants to travel to the eastern or western hemisphere, many routes pass through Africa and this makes it even more attractive as a strategic location for a hub. South Africa plays a crucial role because of its location. From its various locations throughout the world, it could consolidate all goods in one location before shifting them onwards to their final destination in other African countries (Fig. 3). South Africa is the most attractive location of all due to being equidistant between both coasts of Africa, both of which have significant oil and gas resources. This chapter is based on the case study of South Africa and the supply chain design according to the main challenges to deal with.

### *2.1 Features*

South Africa is the most developed economy in Africa (Market Line 2013). The country boasts of a strong financial sector and a stock exchange that is the 15th largest in the world (Central Intelligence Agency 2013), while it ranks in the top ten emerging markets, a result of its entry into the BRICS club. The Market Line report


**Fig. 3** Establishing supply hub in South Africa

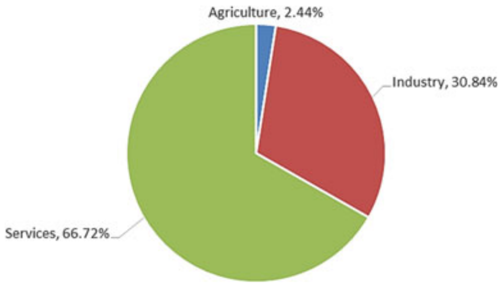


**Fig. 4** GDP composition by sector, 2012

(Market Line 2013) stated that the three existing economic sectors in the country are services, industry and agriculture, as shown in Fig. 4. While services and industry dwarf agriculture in percentage terms, one cannot underestimate the importance of the latter.

The economy has experienced stable progress since the end of the apartheid rule. Between 2004 and 2008, the GDP grew at an average of 4.92 %, but went down to 1.54 % in 2009 after the global economic crisis. The economy managed to pick up again, recording a growth rate of 3.46 % and 2.55 % in 2011 and 2012. The low GDP in 2012 was due to the wildcat strikes in the mining sector. The government of South Africa has budgeted $83.63 billion for building new roads, railways, ports and electricity plants, and upgrading the existing ones.

After transitioning from the apartheid government in the 1990s, there have been significant improvements in the economy and international competitiveness of the country due to emergence of manufacturing and services industry and bulk export commodities such as gold, diamond, minerals, machinery and equipment (Central Intelligence Agency 2013). The CIA fact book reported an estimated $100.7 billion value of export trades in 2012. The freight logistics sector plays an important part in reducing logistics related costs and enhancing the efficient transportation of goods within the country and between its foreign trading partners.

In terms of security, South Africa unfortunately suffers from high levels of crime and violence. Although these have greatly fallen since the turbulent times immediately after independence, when the annual murder rate was a staggering 66.9 per 100,000 people (20), it is very common to hear of rape, car hijackings and other violent crimes even in the heart of the biggest cities. Many South Africans from all walks of life have chosen to emigrate from their homeland as a direct result of these daily threats. The loss of such people, many of them skilled professionals and businesspeople has proved a severe blow to the nation. A large number of the more affluent South Africans tend to seek refuge in gated communities, which seems a good idea on the surface, but in reality, simply serves to widen the gap between them and their less well-off countrymen.

It is true in some ways that the government has made several strides in cracking down on crime in an effort to improve South Africa's image as a safe destination for tourists and stem the outflow of human capital. The murder rate, while still high, has fallen by more than 50 % (20) to date, particularly in heavily industrialized areas like Gauteng, KwaZulu Natal and the Western Cape. Hosting the FIFA World Cup in 2010 caused large scale mobilization of the police and defence forces around the country and led to a much more secure and stable environment than in time gone by.

However, in terms of how a foreign corporation would have to go about staffing its operations, all signs point to either offering premium wages to employees to come to South Africa or recruiting exclusively from the local populace. There are obvious pros and cons to both proposed solutions but we believe that the latter is more sustainable long-term. While the government continues to make progress in combating crime, it is clear that the country has a long way to go before it will be seen as an attractive destination by expatriate workers that will likely seek higher salaries and benefit packages as compared to the local counterparts.

Almost 89 % of goods are transported via road. The country has the longest road network in Africa (South Africa Info 2013) with a total of 62,995 km paved roads and 301,136 km unpaved road network (Central Intelligence Agency 2013). The rail network is mainly used for transporting bulk cargo within the country and to the sea ports for exports. Almost 180 million tons of cargos are transported annually through the 20,192 km (Central Intelligence Agency 2013) rail network. The passenger rail system experienced a revamp during the preparation for the soccer world cup in 2010.

The sea ports play a vital role in South Africa's economy. The eight commercial sea ports serve as a trading point between the country and its trading partners as almost 96 % of export goods go through them. The seaports are also used as hubs for traffic between the Americas, Europe Asia and East and West Africa (South Africa Info 2013). The sea port includes Richards Bay, Durban, East London, Port Elizabeth, port of Ngqura, Mossel Bay, Cape Town and Saldanha.

There are 14 major airports and multiple smaller airports in South Africa with full functionality (Airports, AZ World 2014). The ten largest airports in the country handle more than 200,000 aircraft landings and ten million passengers (Airport Company of South Africa 2013).

Even though the country has a functional transport infrastructure, there is a need to restructure the freight logistics sector in order to sustain economic growth. Some of the causes of inefficiencies, especially in the port and rail transport, reported by the country's department of transport are aging asset base, poor service culture, lack of skilled staffs and low operational efficiency (South African Department of Transportation 2005).

South Africa is part of the Southern African Customs Union (SACU), which also includes Botswana, Lesotho, Namibia and Swaziland. Therefore, a multinational that wants to conduct its operations in South Africa has a clear advantage because it would not have to pay a double tariff on goods brought into one country and sold in another. When one considers the importance of Walvis Bay in international shipping, this is a great opportunity because it allows the company to have more than one outlet in the region and move goods within those countries without the hassle and expense of clearing customs twice (Union, South African Customs 2013).

All customs transactions are carried out by the South African Revenue Service (SARS), which completely controls the entry of goods brought into the republic. It is the obligation of the concerned importing company to report any and all goods that are to remain in the country on an accompanying bill of entry. It is also responsible for ensuring that any and all goods brought into the country for consumption by local citizens is safe and constitutes no hazard for humans and the environment simultaneously (Government, South African 2013).

South Africa currently has a deal with the European Union (EU) in which 86 % of all goods of EU origin (as of 2012) are subject to lower duties and the scheme is reciprocal (the EU accordingly charges lower duty on 92 % of South African-sourced products) (Handbook, SA Investor 2012). A similar agreement has been in place with the USA since 1999 but this has largely been ignored until very recently. Nonetheless, it calls for a bilateral forum in which the two countries will sit down and discuss a framework in which they can simultaneously cut duties on each other's products in a manner similar to that which exists between South Africa and the EU.

South Africa has preferential access agreements (similar to most favoured nation (MFN) status) with Zimbabwe and Mozambique (Handbook, SA Investor 2012). These call for preferential duty rates on a range of products that are sourced in one country and brought to the other, which creates a highly exciting opportunity for a multinational company. For example, an oil company with interests in Mozambique would know that they could tap into the vast oil reserves located over there and send them to South Africa at reduced rates from what would otherwise be quoted.

## 2.2 Solutions Tackling the Problem

### 2.2.1 Qualitative Issues: Customs and Personnel

Nonetheless, the nature of international shipping and transport is such that there are indeed ways for a company to bring products into a country in the shape of raw materials, work in progress or finished goods and still have no payment obligations to the host government. Based on prior work experience in freight forwarding and product movement, there are three methods.

The first method is through providing employment to the local populace in exchange for tax relief. This is essentially a contract between the company and the local or national government whereby the company agrees to reserve a certain percentage of its payroll (normally at least 50 %) for local employees in exchange for tax breaks from the government. The benefits of this are clear, and in a country where there is still high unemployment even in urban centres such as Cape Town, Durban and Johannesburg, an agreement of this sort could benefit both the company and the South African government as it tries to find jobs for its growing population.

Another available option would be the value-added-to-product method. In this way, a company would bring in an ostensibly completed product and somehow improve or modify it using locally sourced products. In this way, the company's presence benefits the local economy (mainly small businesses) before either selling its products within that country's borders or moving them along to another location for sale. In exchange, the government provides a tax break to the goods when they are imported, even if they are in the form of finished goods.

The third option would be if the company actually takes an active role in the country in which it operates. This need not be through charity but as a result of bringing its manufacturing operations (or at least those directly related to products in that country) to a local area and thereby creating business in the country through buying machinery, hiring staff, etc. In a way, this is actually a hybrid of the first two methods because it incorporates elements of both in a way that might well be of interest to the South African government as it seeks to further stimulate the economy.

While taking an active role in the country of operations, the company can also benefit from the local personnel. The census actually shows that the true number of people with some knowledge of English has now increased since 1991. The role of English as a commonly accepted lingua franca for people of all races has seen it ascend to the status of official government language and the first or second language of education in institutes throughout the country, so the younger generations should all be educated to a more than acceptable level of English (Government, South African 2013). Therefore, a company would be well-placed to take advantage of this demographical trend, because they can absorb young, cheap talent and mould it in the way that they would want to.


**Fig. 5** Industrial development zones in South Africa

### 2.2.2 Quantitative Issues: Locations of Industrial Development Zones; Effects in Lead-Time and Cost

The Industrial Development Zones (IDZ) concept is the South African government's version of what are otherwise known as free-trade zones (FTZs) around the world. The official government website describes an IDZ as "A purpose built industrial estate linked to an airport or seaport that leverages domestic and foreign direct investment" (Touche, Deloitte and Deloitte Assets 2013).

There are currently five IDZs in South Africa (from west to east): Saldanha Bay (Western Cape), Coega (Eastern Cape), East London (Eastern Cape), City Deep (Gauteng) and Richard's Bay (KwaZulu Natal) (see Fig. 5).

The brief study in Table 1 focuses on the strengths and weaknesses of the individual IDZs.

The criteria for deciding upon an IDZ are quite broad because there are several qualitative factors at play here. For instance, having the supply base in Cape Town may not appear to be a great idea due to its relative isolation from the rest of urbanized South Africa. However, choosing Saldanha Bay as the main IDZ does have its advantages; not only is the IDZ new and close to the Namibian IDZ of Walvis Bay, but it also offers the quickest route up the Western Coast of Africa. This would be of particular importance to a company that also relies heavily on ports in the Mediterranean or the Low Countries, who would otherwise have to consider sending their sea cargo via the Suez Canal in the case of Richard's Bay or City Deep.

Information on the costs related to the use of the IDZs is sometimes hard to find because both the national government of South Africa as well as the regional

**Table 1** Advantages and disadvantages of IDZ location in South Africa

| IDZ | Advantages | Disadvantages |
|---|---|---|
| Saldanha Bay | – Great linkages to Cape Town<br>– Proximity to Walvis Bay in Namibia in case of overflow | – Sparsely populated, harder to find qualified personnel<br>– Large-scale investment required for development |
| Coega | – Massive space (6500 ha) of industrial land available<br>– Flexible leasing prices in secure areas | – Lack of relocation allowances and tax breaks to investors |
| East London | – Best established IDZ in the country with adequate supply of utilities<br>– Large English-speaking workforce available in Eastern Cape and KwaZulu Natal | – Other IDZs have copied or improved upon existing methods |
| City Deep | – Located in South Africa's industrial heartland; easy distribution to various parts of the country<br>– Best access to air, road and rail networks | – Still in the process of becoming independent from Durban<br>– No access to waterways |
| Richard's Bay | – Located in the heart of Durban, arguably the busiest and best-equipped port in Africa<br>– Most diverse workforce in the whole country | – Plagued by lack of investment compared to the likes of Coega or East London |

governments are continuously investing in the sites to make them as capable as their counterparts in the Northern hemisphere. While this can be an advantage to corporations in the long-run, this is a short-term problem because of the associated cost uncertainty. For example, even though Saldanha Bay is nearly ready to start taking in customers, there is little public information available regarding how much an investor should expect to pay in terms of start-up costs.

While the IDZ concept was initially well-received by the business community, it was plagued by a number of weakness compared to similar schemes elsewhere in Africa (Tanzania) and more traditional tax havens located in Southeast Asia (Newspaper, City Press 2012). Power shortages, a distinct lack of advantages compared to schemes undertaken in Tanzania and other locations such as Singapore and difficulties in getting the flagship IDZ at City Deep off the ground has disillusioned many people. This has led to the government deciding to introduce a scheme known as Special Economic Zones (SEZs). The idea behind the concept is that companies located in foreign countries with high labour and manufacturing costs would be attracted by the relatively cheaper options offered by China (Tank, Polity Think 2013). As labour costs in China began to rise, however, the Chinese government and its subsidiaries decided to export the idea to newer frontiers, e.g. the Asian Tigers and African countries.

A 2013 study by Deloitte's South African think tank suggests that the introduction of SEZs could serve to soften the disappointment felt due to the under-performance of IDZs and bring back confidence in South Africa's reputation as a safe place for foreign companies to invest (Africa, Deloitte South 2013). It is widely felt that the extra features possessed by SEZs compared to IDZs, such as free ports, free trade zones and development zones, will result in the SEZ becoming a sort of "one-stop shop" for foreign companies.

For a multinational seeking to enter into South Africa and take advantage of the opportunities offered in the IDZs/SEZs, it should not really be a cause for concern whether an investment in a current IDZ would be a waste of money upon commencement of the SEZ scheme. The South African government's official website (Government, South African Tourism 2013) states that all three of the functioning IDZs as well as Saldanha Bay will be four of the ten proposed SEZ sites, so it is highly possible that an investment in a current IDZ will eventually end of as part of an SEZ if and when the scheme truly takes hold.

#### 2.2.3 Location of Warehouses

Logic dictates that large, multinational companies would want to base their operations close to large logistics hubs when entering into a new country.

Table 2 is a list of locations identified as having the capacity to be useful should a company decide to set up operations in South Africa. These are the considerations taken into account when proposing potential locations for the warehouse:

I. Connectivity to freight transportation links
II. Proximity to IDZs
III. Access to suitable personnel

### 2.3 *Methodology*

The chapter began with the background of the situation and the literature review, which have been described in the previous sections. Pursuant to this, it is presented the theoretical models, after which it will gather and analyse the data derived and finally come to the conclusions that will assist the oil and gas company in making an informed decision about whether or not to enter South Africa in the long run.

#### 2.3.1 Time Value of Goods

A fair measure of calculating the benefit to the company in cost terms is to calculate the time value of goods, i.e. what is the value of the goods in transit. In this way, it can be calculated the cost savings to the company for reducing the time to get the goods from South Africa to the final destination rather than from one of the origin cities that were previously identified.

The inventory carrying cost will be calculated using the formula below (1). It will be applied for all shipments, be they from the origin cities to South Africa or from South Africa to the final destinations.

**Table 2** Acceptable warehouse locations in South Africa

| Location | Population (25) (million) | Nearest port/ IDZ (26) | Advantages | Disadvantages |
|---|---|---|---|---|
| Cape Town, Western Cape | 3.35 | Cape Town/ Saldanha | – Proximity (1 h 40 min) to Saldanha IDZ<br>– Major location of English speakers | – Largely isolated from other urban centres in South Africa |
| Johannesburg, Gauteng | 3.61 | Richard's Bay or Durban/ Johannesburg | – IDZ within a 15 min drive from the city centre (City Deep)<br>– Large and skilled labour force<br>– Easy access to government offices | – No waterway<br>– Most expensive real estate in South Africa |
| Durban, KwaZulu Natal | 2.84 | Durban/ Richard's Bay | – One of the largest ports in the world, able to handle large amounts of cargo<br>– Well connected to nearly all urban areas in South Africa<br>– Old and established links with the heavily populated Gauteng province | – Crowded, brings in a lot of traffic from East Africa<br>– Distance from the Western African coastline |
| Port Elizabeth, Eastern Cape | 1.3 | Port Elizabeth/ Port Elizabeth | – IDZ located within the city limits (Coega)<br>– Proximity to another IDZ (East London) in the case of overflow)<br>– Easy access to rail, sea, land and air routes for domestic and international transport | – Poor Human Development Index (HDI) record, difficulties in sourcing capable personnel |

$$Inventory\,Carrying\,Cost = \frac{CCC}{365} * No.\,of\,Days\,in\,Transit * Value\,of\,Goods \quad (1)$$

For example, if the case of Aberdeen to Angola is considered, in the as is scenario the lead time to Angola by air is 5 days (actually 4.42 but it is rounded up to the next day), so the TVG would be: TVG $= 0.11/365 \times 5 \times 3{,}767{,}658.28 =$ \$5677.29. In the to be scenario, the lead time is shorter (South Africa to Angola is 2 days, according to documents provided by the company), the inventory carrying cost would be two and a half times less or just \$2270.92.

### 2.3.2 Current Situation

In order to establish a benchmark and understand the company's current situation, the total cost under the status quo and the proposed scenario will be calculated.

$$\begin{aligned} Total\ Cost\ (TC) = {} & Total\ Freight\ Charges(FC) + Total\ Admin\ Costs(AC) \\ & + Total\ In - Transit\ Value(ITV) \end{aligned} \tag{2}$$

### 2.3.3 Calculations

- Freight Charges: No calculations required, since these were included in the data provided by the oil and gas company.
- Admin Costs: By subtracting freight charges from total transport charges,
  e.g. Aberdeen to Angola had FC = \$1,876,561.14 and TC = \$2,331,331.89.
  By definition, then AC = 2,331,331.89 − 1,876,561.14 = \$454,770.75
- In-Transit Value: The data had all values for the cost of the goods being transported, so is used to calculate in-transit value.

### 2.3.4 NPV Components

The whole premise of an NPV calculation is that the net cash flows from the operation in question can be discounted based on the number of years into the future.

$$\mathrm{NPV} = -\mathrm{CF0} + \mathrm{CF1}/(1+\mathrm{r}) + \mathrm{CF2}/(1+\mathrm{r})2 + \ldots + \mathrm{CFn}/(1+\mathrm{r})\mathrm{n} \tag{3}$$

where CF0 is the initial investment (if any), CF1,...,CFn are the corresponding cash flows, r is the discount rate used (we shall use 11 %, for the present case company) and n is the number of years in the analysis.

In order to calculate the net cash flows, both positive (inflows) and negative (outflows) cash flows have been identified:

Inflows

Savings—This term is defined as any money that the company will save as a result of shorter transit times, which entails lower in-transit value. This can also happen in the long-term because, the in-transit value from the original six countries to South Africa is considered negligible, as it is assumed that all shipments will be made to South Africa in one instance. Nonetheless, there will still be a carrying cost associated with this, that will be included in the transportation cost in subsequent years (year 2 onwards).

Outflows

1. In-Transit Cost—as discussed, this cost will only take place during the first year because the in-transit cost from South Africa to the destination countries has been factored into the total transport cost from year 2 onwards.
2. Transport Cost, which is the expense generated by the company in its transportation operations.
3. Administrative Cost—as a percentage of transport cost.
4. Salary Expense—this will be the least significant component of the cash outflows (the company estimates that the staff will be rather small at first).

### 2.3.5 Savings

The only carrying cost associated with the first leg of the shipment will be included in the transportation cost for subsequent years, so the equation to be used will be:

$$\begin{aligned} \text{Savings} = {} & \text{Total InTransit Value Under Status Quo} \\ & - \text{InTransit Value from SA to Destinations} \end{aligned} \tag{4}$$

For the company, staff in its other locations is divided into labour and administrative personnel, leading to (5):

$$\begin{aligned} \text{Salary Expense} = {} & \text{No. of Admin Staff} * \text{Admin Salary} \\ & + \text{No. of Labour Staff} * \text{Labour Salary} \end{aligned} \tag{5}$$

### 2.3.6 Discounting Cash Flows

There will be used a discount rate r of 11 % in order to maintain consistency with the company data. Therefore, calculating the discount rate for each year is simply:

$$(1 + 0.11)n = 1.11n$$

where n is the year in question. For example, the discount rate in year 1 is just 1.11, while in year 2, it would be 1.112 = 1.21, up to and including 1.1110 = 2.84 in year 10.

### 2.3.7 The NPV

After calculating the net nominal cash flows, then they will be discounted by the scale factors. Then based on Eq. (3), the NPV will be calculated:

$$\text{NPV} = \$10,691,808.16$$

As it can be seen, the company may gain a have respectable return of \$10.7 M (in present terms) on its investment of approximately \$90.3 M, which is a return on investment (RoI) of 11.8 %, should it decide to implement the proposed scenario and set up a supply base in South Africa.

## 2.4 Results

As shown in the previous results, setting up the supply base in South Africa is not an investment that would reap immediate dividends. Rather, it is advisable to term it an investment in the future.

The project actually makes a loss in the first 3 years, does not turn a profit until year 4 and only breaks even/starts producing a return in year 8. The NPV of the project based on a 10-year horizon is approximately \$10.7 M.

This may not appear like a great return on investment (ROI) at first glance. Although there is no real up-front investment as far as our the company of study is concerned (they will rent space at an IDZ as opposed to buying it, while ground operations in South Africa and its other African locations are handled by third parties), the calculations suggest that they will spend around \$90.3 M in present value over the course of the 10 years we investigated, which equates to an ROI of about 11.8 %.

Nonetheless, as it was stressed earlier, this project is one for the future and most of the financial loss is over within the first 3 years. In addition, the economies of scale and advantages in lead-time (goods transported from South Africa to other African countries will arrive more quickly than from other bases worldwide) mean that more savings will be realised as time passes.

## 2.5 Sensitivity Analysis

In order to identify the impact of different sources of uncertainty in the model proposed, a sensitivity analysis will be performed.

For the calculations shown in this chapter, the exact conditions under which the historical data was derived for the proposed scenario were simulated.

Therefore, while running a single NPV calculation is well and good for the purpose of establishing a baseline, a thorough sensitivity analysis is also desirable in this case because it allows us to test for weaknesses in the model and identify at which points, a company may encounter difficulties. To do this, the effects of changing one variable while leaving all others consistent will be explored.

**Table 3** Additional annual cost with respect to annual cost of goods in transit

| Annual COG | $1,166,038,126.75 | |
|---|---|---|
| Annual in-transit | $5,271,131.26 | % of Total |
| 10-day strike | $146,420.31 | 3 |
| 15-day strike | $219,630.47 | 4 |
| 20-day strike | $292,840.63 | 6 |
| 30-day strike | $439,260.94 | 8 |

**Table 4** Effect in fuel price upon NPV

| % Increase in fuel price | Resultant NPV |
|---|---|
| 5 | $10,153,183.02 |
| 10 | $9,614,557.89 |
| 10.97 (average) | $9,510,064.61 |
| 15 | $9,075,932.76 |
| % Increase in fuel price | Resultant NPV |
| 5 | $7,049,966.27 |
| 10 | $3,408,124.39 |
| 15 | –$233,717.50 |
| 17.83 % (average) | –$2,297,687.75 |

Labour strikes are a huge cause for concern in South Africa due to the crippling effects they have had on other companies in the minerals industry. The sensitivity analysis performed focused on what would happen in the event of 5, 10, 20 and 30 working days being lost due to strikes.

Table 3 shows what the additional annual cost to the company would in absolute and percentage terms with respect to the annual cost of goods in transit. This may not be such an issue in other countries where labour strikes are not so frequent, but in this case, it would not be an exaggeration to suggest that significant time could be lost annually.

Another point to be aware of is the volatility of fuel prices. This is more prevalent in sea cargo (where prices have increased by 17.83 % annually in the period 2009–14) than in air cargo (an increase of 10.97 % from 2000 to 2013) but it is a major component of freight charges. In fact, it has been estimated that fuel prices account for 9.5 % and a massive 70 % of aviation and bunker (ship) fuel, respectively.

Table 4 above show the effect that each respective increase in fuel price would have upon the NPV we calculated ($10.7 M) before taking extraordinary circumstances into account. The effects were calculated for a range of increases because the two figures previously calculated were both averages, so it is interesting to see the effects of each one.

## 3 Recommendations

Based on the results shown above, the lessons learnt with the oil and gas company subject to study can be extensive to the industry sector in general (at least those interested in a new design of their supply chains while accessing to new markets) in the African continent:

- In reference to the right location or hub creation, there are several mitigating factors for choosing the best one:
  - The products sent by sea are frequently heavy and would be cumbersome and more expensive to transport to the coast from Johannesburg. Besides, Johannesburg airport is under 8 h away from Richards Bay, so deliveries can be made daily if so desired, therefore negating fears that cycle time would drastically increase.
  - Richards Bay is where a large proportion (43 %) of the total annual tonnage passes through South Africa, so the company could secure lower truck rates towards the South African hinterland due to the large number of empty trucks (most companies would export from the ports) when air cargo is needed.
  - Richards Bay and Durban are just 2 h apart by truck, so any capacity restrictions at the base in Richards Bay can be easily solved with a short ride down the coast of the Eastern Cape. When combined, the two locations described have: 64 % of annual tonnage, 56 % of container traffic and 49 % of all vessels that dock in South Africa's seaports every year.
- Rent premises/equipment at the beginning so that the cost of exit is not terribly high in the event that the company decides to discontinue the project after a while.
- Frequently benchmark these results against historic examples of the company's expansions in other parts of the globe.
- Consider more air freight than sea freight, especially for non-bulky items. Sea freight is highly dependent upon the price of bunker fuel, which increases at a much higher rate than aviation fuel.

## References


Africa, Deloitte South (2013) [Online]. http://www.deloitte.com/assets/Dcom-SouthAfrica/Local%20Assets/Documents/Deloitte_Special_Economic_Zones_2013.pdf

African Development Bank (2009) Oil and gas in Africa. Oxford University Press, New York. ISBN 978–0–19–956578–8

Airport Company of South Africa (2013) Total passenger traffic [Online] [Cited: 26 Nov 2013]. http://www.acsa.co.za/home.asp?pid=117

Airports, AZ World (2014) South African airports [Online]. http://www.azworldairports.com/azworld/p2480.cfm

At Water's Edge (2011) Base assumptions: predicting China's first overseas naval base [Online] 5 Oct 2011. http://atwatersedge.org/tag/navy/

Carroll J (2013) Russia's oil lead challenged as taxes strangle drilling. Bloomberg.com [Online]

Central Intelligence Agency (2013) The world fact book: South Africa [Online] 18 Nov 2013. https://www.cia.gov/library/publications/the-world-factbook/geos/sf.html

Chima CM (2007) Supply-chain management issues in the oil and gas industry. J Bus Econ Res 5(6):27–36

Ernst and Young (2011) Driving improved supply chain results: adapting to a changing global marketplace [Online]. http://www.ey.com/Publication/vwLUAssets/The_COO_perspective_-_at_a_glance/$FILE/The%20COO%20perspective%20-%20at%20a%20glance.pdf

Government, South African (2013) Tourism 2 [Online]

Government, South African (2013) Tourism 3 [Online]. http://www.southafrica.info/about/people/language.htm#english

Government, South African (2013) Tourism [Online]. http://www.southafrica.info/business/economy/development/sez-200413.htm#.UrPtf_RDuVs

Handbook, SA Investor (2012) [Online]. http://www.dti.gov.za/DownloadFileAction?id=645

KPMG Africa Limited (2013) Oil and gas in Africa: Africa's reserves, potential and prospects

Market Line (2013) South Africa: in-depth PESTLE insights. 06/2013. ML00002-025.

Newspaper, City Press (2012) [Online]. http://www.citypress.co.za/business/idzs-programme-has-missed-the-mark-october-20120121/

PricewaterhouseCoopers (2013) From promise to performance: Africa oil and gas review

South Africa Info (2013) South Africa's transport network. South Africa info [Online]. 11 Nov 2012 [Cited: 26 Nov 2013]. http://www.southafrica.info/business/economy/infrastructure/transport.htm#.UpMke8Skrjg

South African Department of Transportation (2005) The national freight logistics strategy

Tank, Polity Think (2013) [Online]. http://www.polity.org.za/article/special-economic-zones-can-south-africa-follow-in-the-dragons-footsteps-2013-08-29

The Economist (2013) South Afica's language: tongues under treat [Online]. 20 Jan 2013 [Cited: 24 Nov 2013]. http://www.economist.com/node/17963285

Touche, Deloitte and Deloitte Assets (2013) [Online]. http://www.deloitte.com/assets/Dcom-SouthAfrica/Local%20Assets/Documents/Deloitte_Special_Economic_Zones_2013.pdf

Union, South African Customs (2013) [Online]. http://www.sacu.int/

U.S. Energy Information Administration (2013) International energy statistics [Online]. http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=3&pid=3&aid=6&cid=r6,&syid=1980&eyid=2013&unit=TCF

# Urban Logistics: Multi-modal Transportation Network Design Accounting for Stochastic Passenger Demand and Freight Logistics

**Narges Shahraki and Metin Türkay**

**Abstract** In this chapter, we present a bi-level optimization model by considering multiple transportation modes, stochastic passenger travel demand and freight logistics. Passenger travel demand can follow a general probability distribution where its mean and variance are function of the population in the origin and destination areas. The problem is formulated as a bi-level optimization problem. In the lower level, transportation design problem is formulated to minimize traveler costs and in the upper level we consider minimizing carbon monoxide emission and minimizing probability of traffic congestion. The two-stage model is formulated as a single stage model by considering optimality condition of lower level problem as a set of constraints in the upper level model. The formulated single stage model is a Mixed-Integer Non-linear Programming (MINLP) problem. In this chapter, a stochastic multi-modal, bi-level optimization model is presented for passenger and freight transportation problem in urban regions.

## 1 Introduction

The urban logistic systems incorporate an efficient, reliable, safe and environmentally friendly solution to urban freight transportation problem. Due to increasing population in urban areas, the importance of urban logistics is expected to increase in the next decade (Taniguchi et al. 2014). Ever increasing population and also the diversity of products and services required by the citizens, commercial establishments and service providers puts significant pressure on policy makers to regulate city logistics while keeping high service levels. Some of these policy measures include the use of consolidation centers, regulating access to urban areas by freight vehicles, low or emission free zones, regulation of access and freight delivery times. The main consideration in these policy measures tries to achieve the triple

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bottom line of sustainability: creation of economic value to commercial and service establishments while keeping the costs to citizens under acceptable levels, keeping the environment as clean as possible by eliminating or controlling emissions, noise and achieving livable social environment by providing a diversity of products and services to citizen under acceptable service levels.

Many of the decisions regarding the urban logistics can be categorized into three levels: strategic, tactical and operational. At the strategic level, long-term decisions such as establishment of transportation networks, the selection of transportation modes are included. The tactical decisions are usually related to medium-term decisions such as capacity utilization at the consolidation centers, the schedules of regular transportation systems. The operational decisions are short-term and include the selection of particular vehicles for deliveries and their routes. Although classical logistics problems mainly focus on operational decisions, the urban logistics focuses on strategic and tactical problems. This is mainly due to the fact that the problem is relatively new and many policy makers are trying to understand and address urban logistics problems with the help of researchers. Majority of the work is targeted towards developing an understanding and therefore some solutions to urban logistics problems with the help of innovative models (Taniguchi et al. 2014).

The proposed solutions to urban logistics problems can be viewed in three broad categories:

1. Infrastructure: Shared or dedicated infrastructure elements are used in majority of the cases. Shared infrastructure elements refer to the ones that are used by vehicles transporting people and freight together. Dedicated infrastructure is used only by vehicles transporting people or freight.
2. Capacity: Adding more transportation capacity by expanding network to accommodate more flow is another solution. This solution can be used for by shared and dedicated infrastructure.
3. Restrictions: Restricting the flow of certain vehicles or materials from certain residential zones or times is also a common solution that is used by policy makers.

In this chapter, we focus on the transportation network design problem in urban areas. One of the main considerations in the urban transportation systems is the shared infrastructure by vehicles transporting people and freight mainly in the road transportation segment. We provide an optimization model from policy makers perspective to optimize the design of the transportation network.

## 2 The Urban Transportation Network Design Problem

Traffic congestion and environmental issues associated with transportation have been found as serious problems faced by modern cities because of their negative effects on productivity, health, and living conditions. Research has indicated that on the average, road transportation contributes 95 % of the carbon monoxide (CO) and 35 % of the nitrogen oxides in urban environments (EPA 2010; FHWA 2006). These pollutants are shown to have serious effects on both the ecosystem and the human health (Ng and Lo 2013). Nowadays, governments attempts to control the traffic volume in urban areas to improve or maintain the air quality of the cities and achieve a more sustainable mobility (Zhong et al. 2012).

By rapidly increasing population and growing cities around the world, more people compete for limited urban road infrastructure to travel. Therefore, it is important to understand how the space in cities should be managed to improve accessibility for travelers as well as improve sustainability in cities. Recently, many researchers proposed modeling and optimization tools, which will contribute on how to redistribute limited city space to multiple transportation modes and to understand what level of sustainable mobility can be achieved with different structure.

By growing urbanization, research focused on the network design problem in urban areas during the last five decade (Farahani et al. 2013). The earliest works modeled road network design problem purely based on the static approach, or their stochastic extensions are for depicting the route choice behavior of travelers or for determining the best system performance (e.g., Ban et al. 2006; Boyce and Janson 1980; Chen et al. 2006, 2010a, b; Chiou 2009; Davis 1994; Farvaresh and Sepehri 2012; Friesz et al. 1993; Leblanc 1975; Long et al. 2010; Marcotte 1986; Meng et al. 2001; Miandoabchi et al. 2013; Qiu and Chen 2007; Szeto et al. 2013; Ukkusuri et al. 2007; Lin and Xie 2010; Yang et al. 2010). This approach allows analyzing the problem easily but cannot capture the realistic variations in demand. The travel demand highly depends on the pattern of activities in urban areas. The timing and locations of these activities indicate that travel demand is not uniform through a day (Sheffi 1985). It is also shown that travel demand shows strong variations in a day (Kitamura and Susilo 2005). In addition a large number of static network design studies focus solely on the economic dimension of sustainability (e.g., Ban et al. 2006; Kim et al. 2007; Lo and Szeto 2009). Some researches considered environmental index as the objective (Yafeng and Huapu 1999; Zhou et al. 2008; Huang et al. 2010).

Miandoabchi et al. (2011a, b) developed bi-modal formulations by considering static demand in each period. Szeto et al. (2013) developed a sustainable model for the urban network design. In this model, environmental, economic and social dimensions of a sustainable system are considered as a multi-objective formulation. But in this model demand in each period is constant and only bi-modal transportation is considered. Meta heuristic solution algorithms are implemented to solve these models.

Only a few studies have incorporated all three aspects of sustainability to formulate the network design problem. In addition, these formulations solely consider on-road modes and travel demand is assumed to be static. We address these shortcomings by incorporating the three aspects of sustainability, rail transportation, and stochastic demand into our model formulation.

Urban network design problems are complex since different groups are involved in decision-making process. Therefore, these problems are usually modeled as bi-level problems. There is no general format to develop an exact solution algorithm for these problems with stochastic demand. In this paper, we present a novel solution algorithm to solve the model formulation exactly.

This paper contributes to urban transportation research by including innovations in the model formulation and the design of a novel solution algorithm for multi-modal transportation network design problem with stochastic demand and considering sustainability.

In this paper, we develop a multi-modal transportation model by considering on-road (private cars and buses) and rail vehicles (trams and metros). Travel demand is considered as a random variable that can follow any distribution where its mean and variance are function of origin and destination populations. We define a reliability index to measure probability of traffic congestion in the network. The presented model incorporates sustainability since we consider minimizing transport emissions and minimizing the probability of traffic congestion as objective functions of upper level problem and minimizing travel cost as objective function of lower level problem. Minimizing transport emissions, minimizing the probability of traffic congestion and minimizing travel cost are environmental, social and economic aspects of our model. In addition in this study we present a novel solution algorithm for this problem. In this research, the closed form expressions of optimality conditions of the lower level problem are formulated. These optimality conditions can generate all local optimal solutions of the lower stage problem. We incorporate these optimality conditions in the upper level problem as a set of constraints. The integrated model has two objective functions and it is a Mixed Integer Nonlinear Programming (MINLP) problem. MINLPs are categorized as the most difficult problems as they include both discrete and continuous variables and involve nonlinearity in the objective function and constraints. Several methods proposed to solve MINLPs, including NLP-based branch and bound (Nabar and Schrage 1991), Generalized Benders Decomposition (Geoffrion 1972), and outer approximation (OA) (Duran and Grossmann 1986). In this study, OA algorithm is used to establish a base for the custom solution algorithm. This method involves repeatedly solving the NLP sub problems, generated by fixing the values of discrete variables, and the Master problem, constructed by replacing the nonlinear functions by their linear approximations, until the bounds from these two problems converge. In this study, we add an additional condition for optimality to OA algorithm to make sure the optimal solution is a global solution for the lower level problem since the lower level problem is non-linear and the KKT conditions can generate all local solutions. In this paper, we use OA and $\epsilon$-constraint algorithms to develop our algorithm to solve the bi-objective MINLP network problem.

## 3 Mathematical Model

Let $G(N, A, M)$ be a multi-modal network with nodes set $N$, arcs set $A$ and transport modes (i.e., light-rails, metros, passenger cars, buses and so on) set $M$. Some nodes are considered to be origin nodes and some to be destination nodes; the remaining nodes are called intermediate nodes, as shown in Fig. 1. Origin and destination nodes can represent the same geographical location. $P$ is the set of origin nodes, $Q$ is the set of destination nodes, $R$ is the set of routes between pair $p$-$q$. Multi-modal network design problems have intrinsically more than one objective, since the design alternatives must be assessed based on various criteria of network users and the network authority (Miandoabchi et al. 2011b).

In this problem, we divide the residents into $k$ different groups based on their income. They try to choose their route and transports to reach their workplaces in destination nodes ($q$) based on minimizing their travel cost. In addition, we consider that the network planner also has resources to improve the network by augmenting the capacity of the existing links and constructing new buses and subways facilities in the network. The developed model has two stages the travelers determine their route and transports based on minimizing their travel cost in the lower level problem. In the upper level the network planner tries to minimize carbon monoxide (CO) emission and minimize the probability of traffic congestion in the network by allocating new transport facilities and extending the link capacities. CO emission is considered because of three reasons, (1) almost all CO emissions in the air are produced by vehicles, (2) CO is the most important pollutant among the different types of vehicular emissions, which include nitrogen oxide, CO, nitrogen dioxide, sulfur dioxide, ozone, and particulates, and (3) the emission rates of other pollutants are similar to that of CO (Li et al. 2012).

In this study, we assume a basic network with two-way links exists in advance where all bus routes share the street lanes with automobiles. Automobile and bus flows on shared lanes influence each other, and thus the travel time/cost function for these two modes is asymmetric. We focus on network planning and not the actual operation, so we should propose a formulation that can handle large networks. The existing bus and subway lines are given. Attributes of network links such as capacities, length and free travel times are known. Besides, we know candidate

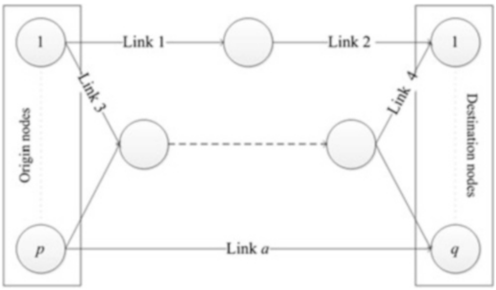


**Fig. 1** Schematic representation of a network

links for constructing bus and subway lines, and total budget for constructing new bus and metro lines and expanding capacity of links. In this study we assume same link structure for both rail transports and on road transports. In addition, the value of walking, waiting and free flow travel times, automobile toll, bus and subway fares are given. The outputs of model are the expansion of links, auto, bus and subway flows on each link, and new bus and subway lines added to the existing network links.

## 3.1 Mathematical Model for Multi-modal Transportation Network Design with Uncertain Demand

We assume that the transportation demand from origin to destination nodes, $d_{pq}$, is a random variable that follows a general distribution with a mean and variance as shown in Eqs. (1) and (2):

$$E\left(d_{pq}\right) = \overline{d}_{pq} \quad \forall p \in P, \forall q \in Q \tag{1}$$

$$var\left(d_{pq}\right) = \sigma_{pq} \quad \forall p \in P, \forall q \in Q \tag{2}$$

Demand between pair $p$ and $q$ follows a general distribution which its mean and variance are equal to a value between zero and amount of population in zone $p$ and $q$. So we can define a general formula for mean and variance of demand as shown in Eqs. (3)–(5).

$$\sum\nolimits_{q \in Q} \overline{d}_{pq} = \alpha\left(H_p\right) \quad 0 \le \alpha \le 1, \forall p \in P \tag{3}$$

$$\sum\nolimits_{p \in P} \overline{d}_{pq} = \beta\left(E_q\right) \quad 0 \le \beta \le 1, \forall q \in Q \tag{4}$$

$$\sigma_{pq} = \Omega\left(\overline{d}_{pq}\right) \quad 0 \le \Omega \le 1, \forall p \in P, \forall q \in Q \tag{5}$$

where $H_p$ and $E_q$ are population amount in origin and destination nodes, respectively.

We assume that demands from origin to destination nodes are mutually independent. The flow in each link (passenger per hour) is defined as the function of travel demand according to Eq. (6).

$$\overline{\acute{x}_a} = \sum\nolimits_{p \in P} \sum\nolimits_{q \in Q} \sum\nolimits_{r \in R_{pq}} d_{pq} \gamma_{pqr} \delta_{pqra} \quad \forall a \in A \tag{6}$$

In Eq. (6), $\gamma_{pqr}$ is the vector of route choice proportions and $\delta_{pqra}$ is the link-path incidence matrix that is equal to 1 if the route $r$ passes through link $a$ otherwise it is equal to 0. We assume that $x_a$ follows normal distribution with mean $\overline{\acute{x}_a}$ in Eq. (7). The variance of the link flow can be expressed as a function of the mean origin-destination demands, route choice proportions, and link-path incident matrix as shown in Eq. (8).

$$\overline{\acute{x}_a} = \sum\nolimits_{p \in P} \sum\nolimits_{q \in Q} \sum\nolimits_{r \in R_{pq}} \overline{d}_{pq} \gamma_{pqr} \delta_{pqra} \quad \forall a \in A \tag{7}$$

$$\acute{\sigma}_a = \sum\nolimits_{p \in P} \sum\nolimits_{q \in Q} \sum\nolimits_{\acute{r} \in \acute{R}_{pq}} \sum\nolimits_{r \in R_{pq}} \sigma_{pq} \gamma_{pqr} \gamma_{pq\acute{r}} \delta_{pqra} \delta_{pq\acute{r}a} \quad \forall a \in A \tag{8}$$

Flow in each link is summation of flow of each transport in each link as shown in Eq. (9).

$$\acute{x}_a = \sum\nolimits_{m \in M} x_a^m \quad \forall a \in A \tag{9}$$

We assume that $x_a{}^{auto}$, $x_a{}^{bus}$ and $x_a{}^{subway}$ are independent and follow normal distribution with means $\overline{x}_a^{auto}$, $\overline{x}_a^{bus}$ and $\overline{x}_a^{metro}$ variances $\sigma_a{}^{auto}$, $\sigma_a{}^{bus}$ and $\sigma_a{}^{subway}$. So, the mean and variance of flow in each link are equal to the summation of each transport mean flow Eq. (10) and variance of each transport flow Eq. (11), respectively.

$$\overline{\acute{x}_a} = \sum\nolimits_{m \in M} \overline{x}_a^m \quad \forall a \in A \tag{10}$$

$$\acute{\sigma}_a = \sum\nolimits_{m \in M} \sigma_a^m \quad \forall a \in A \tag{11}$$

The on road flow is defined as the summation of automobile flow and bus flow. $x_a{}^{auto}$ and $x_a{}^{bus}$ are based on passenger per hour. We define on road flow as Eq. (12) based on the number of autos.

$$x_a = \frac{x_a^{auto}}{\pi} + \omega \frac{x_a^{bus}}{\theta} \quad \forall a \in A \tag{12}$$

where $\pi$ and $\theta$ are average number of passengers in one automobile and in one bus respectively and, $\omega$ is a parameter to convert the bus flow to the equivalent automobile flow. $x_a$ has normal distribution with mean and variance formulated in Eqs. (13) and (14) respectively.

$$\overline{\acute{x}_a} = E\left(\frac{x_a^{auto}}{\pi} + \omega \frac{x_a^{bus}}{\theta}\right) = \frac{\overline{x}_a^{auto}}{\pi} + \omega \frac{\overline{x}_a^{bus}}{\theta} \quad \forall a \in A \tag{13}$$

$$\sigma_a = var\left(\frac{x_a^{auto}}{\pi} + \omega \frac{x_a^{bus}}{\theta}\right) = \frac{\sigma_a^{auto}}{\pi^2} + \omega^2 \frac{\sigma_a^{bus}}{\theta^2} \quad \forall a \in A \tag{14}$$

Equation (15) gives the travel cost function between zone $p$ and $q$ for income group $k$.

$$TC^{pqk} = \sum_{m\in M}\sum_{a\in A} y_a^m \delta_{pqra}\left(vot^k t_a^m + \rho_a^m\right) \tag{15}$$

Above, $t_a{}^m$ is the travel time in each link that is multiplied by the value of time ($vot^k$) of residents of income group $k$, and this expression is added to toll charges ($\rho_a$) to show the travel cost in link $a$. $y_m{}^a$ is equal to 1 if there are flows for transport type $m$ in link $a$ otherwise it is equal to 0. The travel time function for autos on auto links is defined by the BPR function as shown in Eq. (16).

$$t_a = t_0^a\left(1 + \beta\left(\frac{x_a}{Ca_a + e_a}\right)^\alpha\right) \tag{16}$$

In Eq. (16) $t_0{}^a$ is the free-flow travel time of link $a$, and $\beta$ and $\alpha$ are the model parameters. The values for $\beta$ and $\alpha$ are typically considered equal to 0.15 and 4.0 respectively. In this problem the practical capacity of a link is summation of initial capacity of the link ($Ca_a$) plus amount of expansion ($e_a$) which is decision variable in our problem.

The travel cost function of automobiles on a bimodal link is defined by Eq. (17) (Uchida et al. 2006).

$$t_a^{auto} = \check{t}_0^a\left(1 + 0.15\left(\frac{\frac{x_a^{auto}}{\pi} + \omega\frac{x_a^{bus}}{\theta}}{Ca_a + e_a}\right)^4\right) \tag{17}$$

where $\check{t}_0^a$ is the free flow travel time of autos on link $a$.

The travel cost function of passenger buses on bimodal link is defined by Eq. (18).

$$t_a^{bus} = \hat{t}_0^a\left(1 + 0.15\left(\frac{\frac{x_a^{auto}}{\pi} + \omega\frac{x_a^{bus}}{\theta}}{Ca_a + e_a}\right)^4\right) \tag{18}$$

where $\hat{t}_0^a$ is the free flow travel time of buses on link $a$.

So, the long-run perceived travel time for automobiles and buses can be presented respectively in Eqs. (19) and (20).

$$E\left(t_a^{auto}\right) = \check{t}_0^a\left(1 + \frac{0.15}{\left(Ca_a + e_a\right)^4}E\left(x_a^4\right)\right) \tag{19}$$

$$E\left(t_a^{bus}\right) = \hat{t}_0^a\left(1 + \frac{0.15}{\left(Ca_a + e_a\right)^4}E\left(x_a^4\right)\right) \tag{20}$$

The fourth uncentered moment of the distribution can be expressed from the central limit theorem as follows.

$$E\left(x_a^4\right) = \overline{x}_a^4 + 6\sigma_a \overline{x}_a^2 + 3\sigma_a^2 \tag{21}$$

Therefore, we can rewrite the long-run perceived travel time as shown in Eq. (22).

$$E\left(t_a^m\right) = t_a^0\left(1 + \frac{0.15}{\left(Ca_a + e_a\right)^4}\left(\overline{x}_a^4 + 6\sigma_a \overline{x}_a^2 + 3\sigma_a^2\right)\right) \tag{22}$$

where $\overline{x}_a$ and $\sigma_a$ are calculated using Eqs. (13) and (14).

So, Eq. (23) shows the long-run perceived travel cost between nodes $p$ and $q$ for income group $k$.

$$\vartheta^{pqk} = \sum\nolimits_{r \in R_{pq}} \sum\nolimits_{a \in A} \sum\nolimits_{m \in M} \delta_{pqra}\, y_a^m \left(vot^k E\left(t_a^m\right) + \rho_a^m\right) \tag{23}$$

where,

$$E\left(t_a^{auto}\right) = \check{t}_0^{\,a}\left(1 + \frac{0.15}{\left(Ca_a + e_a\right)^4} E\left(\left(\overline{x}_a^4 + 6\sigma_a \overline{x}_a^2 + 3\sigma_a^2\right)\right)\right) \tag{24}$$

$$E\left(t_a^{bus}\right) = \hat{t}_0^{\,a}\left(1 + \frac{0.15}{\left(Ca_a + e_a\right)^4} E\left(\left(\overline{x}_a^4 + 6\sigma_a \overline{x}_a^2 + 3\sigma_a^2\right)\right)\right) + \overline{t}_a^{wk,\,bus} + \overline{t}_a^{wt,\,bus} \tag{25}$$

$$E\left(t_a^{metro}\right) = \acute{t}_0^{a} + \overline{t}_a^{wk,\,metro} + \overline{t}_a^{wt,\,metro} \tag{26}$$

We assume that the waiting time for buses and subways in link $a$ is a random variable with mean $\overline{t}_a^{wt,\,bus}$ and $\overline{t}_a^{wt,\,metro}$, respectively. Also, The time required to access the bus and subway stations on link $a$ via walking is defined as a random variable with mean $\overline{t}_a^{wk,bus}$ and $\overline{t}_a^{wk,metro}$, respectively. So, we rewrite Eq. (20) according to Eq. (25). Equation (26) shows the expected travel time in each link using subways.

CO emission in each link is calculated by Eq. (27). The amount of CO emission for non-electric mode $m$ in link $a$ is function of the length of each link ($l_a$), the travel time in each link ($t^m{}_a$), the travel speed in each link ($l_a/t^m{}_a$) and the number of vehicle type $m$ in link $a$ ($v^m{}_a$) defined as the amount of flow divided by the number of average passengers in one vehicle (Yin and Lawphongpanich 2006; Ng and Lo 2013; Szeto et al. 2013). The amount of CO emission is produced by electric vehicles is zero.

$$ec_a^m = 0.2038 t_a^m \exp\left(0.7962\left(l_a / t_a^m\right)\right) v_a^m \tag{27}$$

Minimizing CO emission, Eq. (27), and maximizing reliability index in Eq. (28) are considered as the first and second objective of upper level problem, respectively. The reliability index is the probability that flow in each link be less the practical capacity ($Ca_a$) of the link plus the amount of capacity expansion ($e_a$) that is a decision variable in our problem. Maximizing the reliability probability is equal to minimizing probability of traffic congestion in the network.

$$\pi = P(x_a \leq Ca_a + e_a) \tag{28}$$

This probability can be obtained from the approximated multivariate normal distribution (Genz 1992). You can refer (Shahraki and Turkay 2014) for more detail. Covariance of flow between links to calculate this probability is calculated according to Eq. (29).

$$cov(x_a, x_{\acute{a}}) = \rho\sqrt{\sigma_a \sigma_{\acute{a}}} \tag{29}$$

where $\rho$ is correlation coefficient.

## 3.2 Optimization Model

Upper level model is formulated by Eqs. (30)–(39). In this level the decision maker is network planner. The decision maker goals are minimizing air pollution and maximizing network reliability as shown in Eqs. (30) and (31) as the objective functions respectively. Equation (32) show there is limited budget for constructing bus and subway facilities. $F^m_{cost}$ is the unit fixed cost (for 1 km) for constructing facilities for mode $m$. There are maximum and minimum values for capacity expansions in Eq. (33). Equation (34) shows binary variables in the links, in which there are not any bus or subway facilities, to allocate bus or subway facilities to these links or not. Eqs. (35)–(39) present minimum and maximum flows in order to have bus or subway facilities in each link.

### 3.2.1 Upper Level Model

$$Min \sum\nolimits_{a \in A} \sum\nolimits_{m \in M} 0.2038 y^m_a t^m_a \exp\left(0.7962\left(l_a/t^m_a\right)\right) v^m_a \tag{30}$$

$$Max P(x_a \leq Ca_a + e_a) \tag{31}$$

subject to

$$\sum\nolimits_{m \in bus, metro} \sum\nolimits_{a \in A} F^m_{cost} \overline{x}^m_a d_a \leq B \tag{32}$$

$$0 \leq e^{min}_a \leq e_a \leq e^{max}_a \quad \forall a \in A \tag{33}$$

$$y_a^m = 0\, or\ 1\ \forall a \in A_2, \forall m \in bus, metro \tag{34}$$

$$\overline{x}_a^{metro} \geq f_{min}^{metro} y_a^{metro}, \forall a \in A_2 \tag{35}$$

$$\overline{x}_a^{metro} \leq M\, y_a^{metro}, \forall a \in A_2 \tag{36}$$

$$\overline{x}_a^{bus} \geq f_{min}^{bus} y_a^{metro}, \forall a \in A_2 \tag{37}$$

$$\overline{x}_a^{bus} \leq M\, y_a^{bus}, \forall a \in A_2 \tag{38}$$

$$\overline{x}_a^{auto} \geq 0, \forall a \in A \tag{39}$$

In this research system optimum (SO) formulation is used to formulate lower level problem instead of user equilibrium formulation (UE), since SO formulation is more normative in nature than UE (Sheffi 1985). Lower level model is formulated in Eqs. (40)–(54). In this model, travelers try to select their route and their modes to move from origin to destination nodes based on minimizing their travel cost (formulated as the function of total travel time including waiting times) as objective function in Eq. (40). Equations (41)–(54) are model constraints. Equation (41) shows the summation of route choice proportion between origin and destination nodes should be equal to 1. Mean and variance of demand for each mode between origin $p$ and destination $q$ are formulated in Eqs. (42), (43) and (44). Besides, mean and variance of flow for each mode in link $a$ are formulated in Eqs. (45) and (46) respectively. Equations (47)–(50) show if there are subway and bus facilities in link $a$ or not. In addition mean and variance of in road flow are formulated in Eqs. (51) and (52) respectively. Equations (53) and (54) shows mean flow of each mode in link $a$ and route choice proportion should be positive.

### 3.2.2 Lower Level Model

$$\min \sum_{p \in P} \sum_{q \in Q} \sum_{k \in K} \vartheta^{pqk} \tag{40}$$

subject to

$$\sum_{r \in R_{pq}} \gamma_{pqr} = 1 \tag{41}$$

$$\sum_{q \in Q} \overline{d}_{pq} = \alpha(H_p) \quad 0 \leq \alpha \leq 1, \forall p \in P \tag{42}$$

$$\sum_{p \in P} \overline{d}_{pq} = \beta(E_q) \quad 0 \leq \beta \leq 1, \forall q \in Q \tag{43}$$

$$\sigma_{pq} = \Omega(\overline{d}_{pq}) \quad 0 \leq \Omega \leq 1, \forall p \in P, \forall q \in Q \tag{44}$$

$$\sum_{m \in M} \overline{x}_a^m = \sum_{p \in P} \sum_{q \in Q} \sum_{r \in R_{pq}} \overline{d}_{pq} \gamma_{pqr} \delta_{pqra} \quad \forall a \in A \tag{45}$$

$$\sum_{m\in M}\sigma_a^m = \sum_{p\in P}\sum_{q\in Q}\sum_{\acute{r}\in \acute{R}_{pq}}\sum_{r\in R_{pq}}\sigma_{pq}\gamma_{pqr}\gamma_{pq\acute{r}}\delta_{pqra}\delta_{pq\acute{r}a} \quad \forall a\in A \tag{46}$$

$$\bar{x}_a^{metro} \le M\, y_a^{metro} \quad \forall a\in A \tag{47}$$

$$\sigma_a^{metro} \le M\, y_a^{metro} \quad \forall a\in A \tag{48}$$

$$\bar{x}_a^{bus} \le M\, y_a^{bus} \quad \forall a\in A \tag{49}$$

$$\sigma_a^{bus} \le M\, y_a^{bus} \quad \forall a\in A \tag{50}$$

$$\bar{x}_a = \frac{\bar{x}_a^{auto}}{\pi} + \mu\frac{\bar{x}_a^{bus}}{\theta} \quad \forall a\in A \tag{51}$$

$$\sigma_a = \frac{\sigma_a^{auto}}{\pi^2} + \mu^2\frac{\sigma_a^{bus}}{\theta^2} \quad \forall a\in A \tag{52}$$

$$\bar{x}_a^m \ge 0 \quad \forall m\in M, \quad \forall a\in A \tag{53}$$

$$\gamma_{pqr} \ge 0 \quad \forall p\in P, \forall q\in Q, \forall r\in R \tag{54}$$

The presented mathematical model, Eqs. (30)–(54), is a bi-level MINLP problem. The objective function of lower level problem is convex as proven but the feasible region is non-convex due to bi-linear and tri-linear terms in Eqs. (45) and (46).

There are several possible reformulations of the bi-level programming problem into ordinary one-level problem. One-level programming problem clearly can be used to derive necessary and sufficient optimality conditions for the bi-level programming problem. One of the possible reformulation approaches to change the problem to one-level is using the Karush-Kuhn-Tucker (KKT) conditions of the lower level model. The single level problem is equivalent to the bi-level programming problem provided that the lower level problem is convex. Without convexity assumption, the single level problem has a larger feasible set including not only global solutions of the lower level problem but also all local optimal solutions (Dempe 2002).

Suppose that the objective function $f$: $R^n \rightarrow R$ and the constraint functions $g_i$: $R^n \rightarrow R$ and $h_i$: $R^n \rightarrow R$ are continuously differentiable at a point ($\gamma_{pqr}{}^*$, $\bar{x}_a^{m*}$). If ($\gamma_{pqr}{}^*$, $\bar{x}_a^{m*}$) is a local minimum, then the solution satisfies some regularity conditions.

## 4 Illustrative Example

Figure 2 shows the layout of the example network consisting of six nodes, seven links, two origins, and two destinations. The characteristics of links, zones and income groups are listed in Table 1. The capacity of network links is allowed to expand up to 10 % of the existing link capacity. Hence, we have $0 \le y_a \le 0.1\, C_a$. We assume that there are no subway and bus lines in the city. Capital cost for constructing subway and bus lines are equal to 0.0062137 (monetary unit per

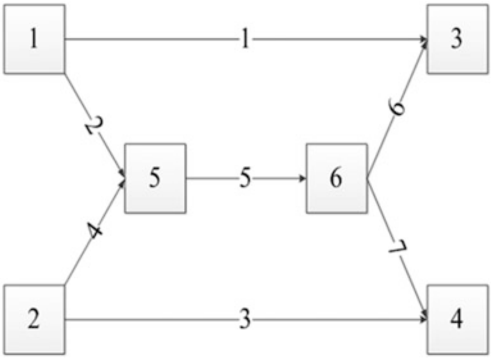


**Fig. 2** The schematic drawing of the illustrative example

passenger-km) and 0.018641 (monetary unit per passenger-km). Correlation coefficients of flow among links are considered according to Table 2. The values of parameters $\mu$, $\pi$ and $\theta$ are considered 3, 2 and 6 respectively. Average metro capacity is assumed equal to 33. ${f_{min}}^{subway}$ and ${f_{min}}^{bus}$ are 30 and 9 respectively. The amount of attraction and production to origin and destination nodes is equal to 100. Means value for waiting and walking times are considered equal to zero (Kumares and Sinha 2007; Davis et al. 2012; Miandoabchi et al. 2011b; Yim et al. 2011; Ma and Lo 2012; Ng and Lo 2013).

The main characteristics of the network is given in Table 1.

The correlation coefficients between the links in terms of traffic intensity if given in Table 2.

When the optimization problem is solved, the optimal solution shown in Table 3 can be found. The main objectives of used budget, total emission and the reliability of the entire network can be monitored for the optimal solution. The allocation of the total budget to creation and expansion of different links are also reported.

## 5 Conclusions

The urban logistic systems have to address the triple bottom line considerations of sustainability by addressing economic, environmental and social issues simultaneously. There are a variety of solutions to urban logistics problem that can be considered at the strategic, tactical and operational levels. In this chapter, we focus on the transportation network design problem in urban areas that is a strategic level decision. One of the main considerations in the urban transportation systems is the shared infrastructure by vehicles transporting people and freight mainly in the road transportation segment. We provide an optimization model from policy makers perspective to optimize the design of the transportation network. We also show that the optimization model can be very useful in developing an assessment of network design decisions from economic, environmental and social aspects.

**Table 1** The characteristics of the illustrative example

| Link # | $\check{t}_0^a$ | $\hat{t}_0^a$ | $t'^a_0$ | $Ca_a$ (veh/h) | $\rho_a^{auto}$ | $\rho_a^{bus}$ | $\rho_a^{metro}$ | $d_a$ (km) |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.13 | 0.13 | 0.1 | 78 | 0.053 | 0.25 (monetary unit) | 0.25 (monetary unit) | 8 |
| 2 | 0.03 | 0.03 | 0.025 | 23 | 0.013 | 0.25 | 0.25 | 2 |
| 3 | 0.15 | 0.15 | 0.1125 | 23 | 0.06 | 0.25 | 0.25 | 9 |
| 4 | 0.05 | 0.05 | 0.0375 | 43 | 0.02 | 0.25 | 0.25 | 3 |
| 5 | 0.1 | 0.1 | 0.075 | 93 | 0.04 | 0.25 | 0.25 | 6 |
| 6 | 0.05 | 0.05 | 0.0375 | 43 | 0.02 | 0.25 | 0.25 | 3 |
| 7 | 0.067 | 0.067 | 0.05 | 43 | 0.027 | 0.25 | 0.25 | 4 |
| Income group | | | | | $vot^k$ | | | |
| High | | | | | 5 | | | |
| Low | | | | | 4 | | | |

**Table 2** Correlation coefficients of flow among links

| Link | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0.2 | 0.3 | 0.05 | 0.1 | 0.2 |
| 2 | 0 | 1 | 0 | 0.1 | 0.2 | 0.3 | 0.2 |
| 3 | 0.2 | 0 | 1 | 0 | 0.4 | 0 | 1 |
| 4 | 0.3 | 0.1 | 0 | 1 | 0 | 0 | 0.1 |
| 5 | 0.05 | 0.2 | 0.4 | 0 | 1 | 0 | 0.2 |
| 6 | 0.1 | 0.3 | 0 | 0 | 0 | 1 | 0.15 |
| 7 | 0.2 | 0.2 | 0.1 | 0.1 | 0.2 | 0.15 | 1 |

**Table 3** The results of the illustrative example

| | | |
|---|---|---|
| Emission index | | 117,025 |
| Reliability index | | 0.874984 |
| Used budget | | 10 |
| Capacity expansion | 1 | 3993 |
| | 2 | 2300 |
| | 3 | 1177 |
| | 4 | 4300 |
| | 5 | 4760 |
| | 6 | 4300 |
| | 7 | 4300 |
| Link flow (subway) (passenger per hour) | 1 | 0 |
| | 2 | 30,000 |
| | 3 | 0 |
| | 4 | 0 |
| | 5 | 200,000 |
| | 6 | 0 |
| | 7 | 87,337 |
| Link flow (auto) (passenger per hour) | 1 | 0 |
| | 2 | 70,000 |
| | 3 | 0 |
| | 4 | 100,000 |
| | 5 | 0 |
| | 6 | 100,000 |
| | 7 | 12,663 |
| O-D mean demand (passenger per hour) | Zone 1–Zone 3 | 0 |
| | Zone 1–Zone 4 | 100 |
| | Zone 2–Zone 3 | 100 |
| | Zone 2–Zone 4 | 0 |
| Optimal route choice | Zone 1–Zone 3 | 100 % from route 1 |
| | Zone 1–Zone 4 | 100 % from route 1 |
| | Zone 2–Zone 3 | 100 % from route 1 |
| | Zone 2–Zone 4 | 100 % from route 2 |

## References

Ban JX, Liu HX, Ferris MC, Ran B (2006) A general MPCC model and its solution algorithm for continuous network design problem. Math Comput Modell 43:493–505. doi:10.1016/j.mcm.2005.11.001

Boyce DE, Janson BN (1980) A discrete transportation network design problem with combined trip distribution and assignment. Transp Res B Methodol 14:147–154. doi:10.1016/0191-2615(80)90040-5

Chen A, Subprasom K, Ji Z (2006) A simulation-based multi-objective genetic algorithm (SMOGA) procedure for BOT network design problem. Optim Eng 7:225–247. doi:10.1007/s11081-006-9970-y

Chen A, Kim J, Lee S, Kim Y (2010a) Stochastic multi-objective models for network design problem. Expert Syst Appl 37:1608–1619. doi:10.1016/j.eswa.2009.06.048

Chen A, Pravinvongvuth S, Chootinan P (2010b) Scenario-based multi-objective AVI reader location models under different travel demand patterns. Transportmetrica 6:53–78. doi:10.1080/18128600902929617

Chiou S-W (2009) A subgradient optimization model for continuous road network design problem. Appl Math Model 33:1386–1396. doi:10.1016/j.apm.2008.01.020

Davis GA (1994) Exact local solution of the continuous network design problem via stochastic user equilibrium assignment. Transp Res B Methodol 28:61–75. doi:10.1016/0191-2615(94)90031-0

Davis SC, Diegel SW, Boundy RG (2012) Transportation energy data book: edition 30–2011. Oak Ridge National Laboratory, Oak Ridge, TN

Dempe S (2002) Foundations of bilevel programming. Springer, Boston, MA

Duran MA, Grossmann IE (1986) An outer-approximation algorithm for a class of mixed-integer nonlinear programs. Math Program 36:307–339. doi:10.1007/BF02592064

Farahani RZ, Miandoabchi E, Szeto WY, Rashidi H (2013) A review of urban transportation network design problems. Eur J Oper Res 229:281–302. doi:10.1016/j.ejor.2013.01.001

Farvaresh H, Sepehri MM (2012) A Branch and bound algorithm for bi-level discrete network design problem. Networks Spat Econ 13:67–106. doi:10.1007/s11067-012-9173-3

Federal Highway Administration (FHWA) (2006) Multi-pollutant emissions benefits of transportation strategies. http://www.fhwa.dot.gov/environment/air_quality/publications/fact_book/index.cfm. Accessed 22 May 2014

Friesz TL, Anandalingam G, Mehta NJ et al (1993) The multiobjective equilibrium network design problem revisited: a simulated annealing approach. Eur J Oper Res 65:44–57. doi:10.1016/0377-2217(93)90143-B

Genz A (1992) Numerical computation of multivariate normal probabilities. J Comput Graph Stat 1:141–149. doi:10.1080/10618600.1992.10477010

Geoffrion AM (1972) Generalized benders decomposition. J Optim Theory Appl 10:237–260. doi:10.1007/BF00934810

Huang K, Zhang J, He M, Liao W (2010) An optimal model and solution algorithm of urban traffic network considering exhaust emission control. In: ICLEM, pp 526–532

Kim BJ, Kim W, Song BH (2007) Sequencing and scheduling highway network expansion using a discrete network design model. Ann Reg Sci 42:621–642. doi:10.1007/s00168-007-0170-2

Kitamura R, Susilo YO (2005) Is travel demand insatiable? A study of changes in structural relationships underlying travel. Transportmetrica 1:23–45. doi:10.1080/18128600508685640

Leblanc LJ (1975) An algorithm for the discrete network design problem. Transp Sci 9:183–199

Li Z-C, Lam WHK, Wong SC, Sumalee A (2012) Environmentally sustainable toll design for congested road networks with uncertain demand. Int J Sustain Transp 6:127–155. doi:10.1080/15568318.2011.570101

Lin D-Y, Xie C (2010) The pareto-optimal solution set of the equilibrium network design problem with multiple commensurate objectives. Networks Spat Econ 11:727–751. doi:10.1007/s11067-010-9146-3

Lo HK, Szeto WY (2009) Time-dependent transport network design under cost-recovery. Transp Res B Methodol 43:142–158. doi:10.1016/j.trb.2008.06.005

Long J, Gao Z, Zhang H, Szeto WY (2010) A turning restriction design problem in urban road networks. Eur J Oper Res 206:569–578. doi:10.1016/j.ejor.2010.03.013

Ma X, Lo HK (2012) Modeling transport management and land use over time. Transp Res B Methodol 46:687–709. doi:10.1016/j.trb.2012.01.010

Marcotte P (1986) Network design problem with congestion effects: a case of bilevel programming. Math Program 34:142–162. doi:10.1007/BF01580580

Meng Q, Yang H, Bell MGH (2001) An equivalent continuously differentiable model and a locally convergent algorithm for the continuous network design problem. Transp Res B Methodol 35:83–105. doi:10.1016/S0191-2615(00)00016-3

Miandoabchi E, Farahani RZ, Dullaert W, Szeto WY (2011a) Hybrid evolutionary metaheuristics for concurrent multi-objective design of urban road and public transit networks. Networks Spat Econ 12:441–480. doi:10.1007/s11067-011-9163-x

Miandoabchi E, Farahani RZ, Szeto WY (2011b) Bi-objective bimodal urban road network design using hybrid metaheuristics. Cent Eur J Oper Res 20:583–621. doi:10.1007/s10100-011-0189-4

Miandoabchi E, Daneshzand F, Szeto WY, Zanjirani Farahani R (2013) Multi-objective discrete urban road network design. Comput Oper Res 40:2429–2449. doi:10.1016/j.cor.2013.03.016

Nabar S, Schrage L (1991) Modeling and solving nonlinear integer programming problems. Annual AIChE meeting, Chicago

Ng M, Lo HK (2013) Regional air quality conformity in transportation networks with stochastic dependencies: a theoretical copula-based model. Networks Spat Econ 13:373–397. doi:10.1007/s11067-013-9185-7

Qiu Y, Chen S (2007) Bi-level programming for continuous network design of comprehensive transportation system based on external optimization. In: IEEE international conference on grey systems and ıntelligent services. IEEE, Nanjing, pp 1186–1190

Shahraki N, Turkay M (2014) Analysis of interaction among land use, transportation network and air pollution using stochastic nonlinear programming. Int J Environ Sci Technol 11 (8):2201–2216. doi:10.1007/s13762-014-0566-3

Sheffi Y (1985) Urban transportation networks: equilibrium analysis with mathematical programming methods. Prentice-Hall, Englewood Cliffs, NJ

Sinha KC, Labi S (2007) Transportation decision making: principles of project evaluation and programming. Wiley, New York, pp 65–93

Szeto WY, Jiang Y, Wang DZW, Sumalee A (2013) A sustainable road network design problem with land use transportation ınteraction over time. Netw Spat Econ. doi: 10.1007/s11067-013-9191-9

Taniguchi E, Thompson RG, Yamada T (2014) Recent trends and ınnovations in modelling city logistics. Proc Soc Behav Sci 125:4–14

Uchida K, Sumalee A, Watling D, Connors R (2006) A study on network design problems for multi-modal networks by probit-based stochastic user equilibrium. Netw Spat Econ 7:213–240. doi:10.1007/s11067-006-9010-7

Ukkusuri SV, Mathew TV, Waller ST (2007) Robust transportation network design under demand uncertainty. Comput Aided Civ Infrastruct Eng 22:6–18. doi:10.1111/j.1467-8667.2006.00465.x

US Environmental Protection Agency (EPA) (2010) Carbon monoxide ımplementation. EPA, Washington, DC

Yafeng Y, Huapu L (1999) Traffic equilibrium problems with environmental concerns. J East Asia Soc Transp Stud 3(6):195

Yang H, Xu W, He B, Meng Q (2010) Road pricing for congestion control with unknown demand and cost functions. Transp Res Part C Emerg Technol 18:157–175. doi:10.1016/j.trc.2009.05.009

Yim KKW, Wong SC, Chen A et al (2011) A reliability-based land use and transportation optimization model. Transp Res Part C Emerg Technol 19:351–362. doi:10.1016/j.trc.2010.05.019

Yin Y, Lawphongpanich S (2006) Internalizing emission externality on road networks. Transp Res D Transp Environ 11:292–301. doi:10.1016/j.trd.2006.05.003

Zhong R, Sumalee A, Maruyama T (2012) Dynamic marginal cost, access control, and pollution charge: a comparison of bottleneck and whole link models. J Adv Transp 46(3):191–221. doi:10.1002/atr

Zhou S, Yan X, Wu C (2008) Optimization model for traffic signal control with environmental objectives. In: Fourth ınternational conference on natural computation. IEEE, pp 530–534

# Tango Without the Dancefloor? The Forgotten Role of the Public Sector on Logistics

**Rein Jüriado**

**Abstract** Logistics is conventionally viewed as a commercially driven activity, linking the manufacturing and distribution of raw materials and finished products. While companies undoubtedly account for a lion's share of the logistics business, a comprehensive perspective on the sector should also include the role of the public sector. The main thesis of the chapter is that many public agencies (on local, regional and global levels) are realising the importance of logistics and are attempting to come to terms with this new need. This will eventually lead to new modes of governance where the public and private sectors will intertwine in new ways.

## 1 Introduction

Logistics is conventionally viewed as a commercial activity. The Council of Supply Chain Management Professionals (2015) defines logistics management as the part of supply chain management that plans, implements, and controls the efficient, effective forward and reverses flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements.

While companies undoubtedly account for a lion's share of logistics operations, the public sector is in many ways the enabler of a functioning logistics system. To use the metaphor of the title, logistics business is largely a business of relationships, such as those between transport operators and cargo owners, between manufacturing and marketing departments, between IT vendors and logistics service providers, between warehouses and hauliers. And yet, for these partners to be able to "dance tango", they all need a framework, such as resilient infrastructure, efficient customs procedures, fair access rules etc., provided by the public sector, what we may call a "dancefloor".

The chapter aims to provide a comprehensive picture of the ways in which public authorities and the government in the broad sense influence and enable the logistics

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business. The chapter will examine three levels of government—local, regional and national—and discuss opportunities for authorities and business to interact, both with the aim of improving the efficiency of the logistics system and bring benefits to the citizens and the society.

The chapter will argue that the role of the public sector has become more prominent in recent years for the benefit of the logistics business. Still better coordination and collaboration between the public and private sectors are needed. Businesses may be more concerned with their competitiveness and government with societal development but both need new modes of governance to achieve their objectives. In particular, the chapter will pinpoint areas for innovation and development needs at the intersection between public and private domains.

## 2 Theoretical Framework and Methodology

### *2.1 Markets and Government*

In economics, the basic free market model of supply and demand does not include government actions. However, economic theories also acknowledge 'market failures', i.e. the allocation of goods and services by a free market is not efficient. In this context efficiency is understood as the case where no-one's situation can be improved without worsening someone else's situation.

Market failures are the reason for governments to intervene in order to achieve an optimal allocation of resources. Regulations, subsidies and taxes are classic examples of government intervention. While these may relieve the cost of market failures to the society, government actions could also lead to an even less optimal outcome, i.e. a 'government failure'. Mainstream economists agree though that in some circumstances government actions will reduce the effect of market failures. For example, in transport regulations on safety have been in place in many countries for decades.

The type and intensity of suitable government interventions are subject to an infinite number of studies and policy papers, often with focus on specific sectors. Transport and logistics are areas with considerable government intervention. In Europe, most infrastructure is owned and maintained by public organisations (even though sometimes works are carried out by private contractors), there are wide-ranging technical regulations in place for all modes of transport, public transport is often subsidised and some cities have introduced congestion charges.

As government interventions have become more common, new settings have emerged where government organisations act as if they were market agents. This has led to the blurring of the border between the private (market) and the public (government) spheres. Activities that used to be associated with the government are increasingly managed jointly across the boundaries of states, sectors and organisations (Jacobsson and Sundström 2001). Ownership and control are the two main criteria that can distinguish public and private (Broadbent and Guthrie 1992). Ownership alone is problematic because some publicly-owned enterprises compete in the free market on equal terms with private ones (Baker 2003).

The new settings involve varied forms of collaboration between the public and private sectors. Public–private partnership (PPP) is a term used frequently although scholars attach different meanings to the term. Some academics see virtually any collaborative arrangement between the public and the private sectors as a PPP (Bovaird 2004), while others regard it as a very specific type of procurement (Shaoul 2002). In this chapter, a broad definition is adopted given the widespread involvement of the government in transport and logistics.

Collaborative arrangements between private and public organisations aimed at achieving social or public objectives with involvement of private agents have emerged in a number of sectors, such as medicine (Buhr 2006), emergency management (Sandebring 2006) and tourism (Bramwell and Lane 2000). These kind of looser partnerships are important because they allow better use of private sector expertise in addressing challenges that both public and private agents are affected by, such as reducing traffic jams decreasing environmental damage caused by transportation (Fischer et al. 2006). The symbolic value of partnering with the private sector may also be important in an age where this is a great deal of scepticism about the efficiency of government (Peters 1998).

Partnerships between public and private organisations imply mutual shared responsibilities. This characteristics distinguishes partnerships from traditional public procurement where a public organisation purchases a fixed service or product from a private organisation that has the sole responsibility for its delivery. In other words, risks regarding service provision in a partnership are shared between the public and private organisations and are ideally managed by the party best equipped to handle a given risk (Hodge 2004; Grimsey and Lewis 2007).

## 2.2 Research Questions

Based on the theoretical framework discussed above, the chapter will examine the ways in which the public and private sectors can build partnerships in the logistics sector. In particular, the chapter will address three layers in which collaboration can occur: local (city) level, regional level and national/transnational level. The chapter will in each case focus on the following questions:

1. What are the key challenges that partnerships between the public and private can jointly address?
2. What are some of the good practices and new modes of collaboration between the public and private spheres?

### 2.3 Methodology

The approach adopted in this chapter is that of case studies. Empirical evidence from European countries has been gathered and will be presented according to the structure mentioned in Sect. 2.2. Since the aim of the chapter is provide a comprehensive overview of the logistics sector and the opportunities for public–private collaboration, limited space does not allow for in-depth analysis of the cases. However, further research should enlighten many of the issues raised.

## 3 Empirical Evidence

### 3.1 Challenges and Experiences on Urban Logistics

Whereas cities have for decades planned for public passenger transport, freight transport has not been equally prominent on the agenda of city authorities. Freight movements to, from and within cities have inherently been influenced by the needs of retail and industrial sectors. Manufacturing and shopping in and close to cities has led to increased freight traffic but until recently urban planners and politicians have largely overlooked urban freight issues (Taniguchi 2012; European Commission 2013).

Cities are increasingly facing traffic congestion. It is estimated to cost the European Union approximately 1 % of its gross domestic product annually and is estimated increase by 50 % by 2050 due to the continuing urbanisation (European Commission 2011). Densely populated urban areas are often most affected by the congestion issues because building new infrastructure is impossible or very expensive. As a consequence of traffic congestion, local emissions, such as particulate matter or NOx, are likely to increase, leading to poor air quality. Trucks account for a disproportionately high share of toxic emissions compared with cars. An estimated 53,000 early deaths occur in the USA due to vehicle emissions (Caiazzo et al. 2013). Traffic-induced noise issues receives increasing attention. A recent report from the World Health Organisation (2011) suggests that 1 million healthy life years are lost annually due to traffic-induced noise in Western Europe. Safety is also affected by the continuing urbanisation. According to European statistics, 69 % of road accidents occur in cities (European Commission 2011). With a greater focus on walking and pedestrian streets, local authorities are imposing new rules on access. Logistics operations must therefore take better care of the needs of vulnerable road users.

The public sector aspires to address these challenges through better policies, while acknowledging that logistics enables economic growth and liveable city centres. This is a balancing act that local authorities have to manage. There is an increasing consensus that they cannot do it without the help from the users, i.e. the logistics business.

The need for a more systemic approach to urban freight by local authorities has been raised by the European Commission among others. Already in 2007, the Commission (2007) identified urban freight as one of the six key action areas in the logistics sector. In particular, a holistic vision covering land use planning, environmental considerations and traffic management was called for. It was also suggested that facilitating freight transport demand management should be an integral part of town planning.

A few years later, the Commission proposed an ambitious vision of essentially CO2-free city logistics in major urban centres by 2030 (European Commission 2011), inspiring many cities across Europe to take joint action towards sustainable city logistics. The Urban Mobility Package and in particular, the accompanying "A call for action on urban logistics" points to the lack of dialogue between city authorities and private companies that operate in urban areas; as well as to the lack of data on freight movements, which makes planning difficult (European Commission 2013).

### 3.1.1 Opportunities for Public–Private Collaboration

Considering the challenges and calls for actions described above, what opportunities for collaboration are there between the public and private sectors on city logistics?

*Joint urban freight strategies* have been developed in a number of cities. By bringing together relevant actors, authorities can lay a foundation for more coherent city logistics policies. The strategies could provide a joint vision across public and private sectors and an action plan detailing the responsibilities of all involved parties. City authorities will also build trust with operators by involving them in defining an urban freight strategy. This will also enable better compliance and acceptance of future rules, such as access restrictions, environmental zones or congestion charging. As example, the City of London has created a Freight Operator Recognition Scheme that provides accreditation to fleet operators serving the city (FORS 2015). By accreditation, logistics providers can prove to existing and potential clients their credentials as operators who adhere to high quality standards with regard to safety, fuel efficiency, economical operations and vehicle emissions.

*Common research and innovation projects* pave way for better knowledge of the freight issue among officials and eventually politicians. Given the relative novelty of urban freight policies, competence can be built through research and innovation projects. Urban freight administrators at local authorities may learn from projects such as BESTUFS and BESTFACT that collect and disseminate best practice on urban logistics. Similarly, the CIVITAS initiative provides a collection of practices on urban freight. Across Europe, research funding agencies are developing programmes to address city logistics. For example, the Austrian research, technology and innovation programme for mobility focuses of four thematic research areas, of which goods transport is one. Major focus is on sustainable urban goods transport. In Sweden, a programme on sustainable and attractive cities has funded a number of city logistics projects. The European Union's research and innovation programme for transport now includes chapters on urban mobility and logistics.

*Public procurement* is a more advanced option but could bring about considerable environmental benefits. The public sector is an important buyer of goods and services, e.g. IT systems, equipment for hospitals, advisory services, as well as works, e.g. new roads and bridges. In the European Union, public procurement accounts for an estimated 16 % of gross domestic product. Globally, the share varies between 10 and 25 % of GDP (European Commission 2015). Freight transport can be a part of public procurement. Depending on jurisdiction of a country, local, regional or national authorities are responsible for a number public services that entail freight movements: food deliveries to hospitals and schools and waste collection are examples of such services. Practices vary largely among authorities with regard to the roles that authorities retain and to those where they contract out to private service providers. Usually a rigorous regulatory framework on public procurement set conditions to how public agencies can contract the private sector and on what grounds contracts should be awarded.

## *3.2 Logistics as a Regional Engine for Jobs and Growth*

Whereas in city centres logistics is mainly an industry that enables everyday life and business, on a regional level it is also a provider of jobs and economic welfare. For decades, trade growth has outpaced the general economic expansion. Between 1990 and 2008, global real gross domestic product (GDP) expanded at an annual rate of 3.2 %, while world trade volumes grew by 6.0 % (PWC 2014). As international trade continues to increase, so does the need for logistics facilities handling the goods volumes.

A further driver for the expansion of logistics sector is the changing composition of the economy in the Western world. Manufacturing jobs continue to be shifted to countries with lower incomes, making regional governments look for options to replace the lost jobs. Logistics is particularly interesting in this context because it provides employment opportunities for blue-collar, white-collar and no-collar workers (Sheffi 2012). At the lower end of the spectrum, many warehousing and trucking jobs are manual and require short training. At the higher end, logistics automation provides job and business opportunities in information and communication technologies, operations and supply chain engineering, financial and flow management etc.

It must, however, be noted that the context in which logistics facilities have expanded in the last few decades may be changing. Since the financial crisis of 2008 world trade has grown slower than GDP. In China, the share of consumption relative to the GDP is growing while exports are not expanding at a rate seen a decade ago. Europe is still struggling in the aftermath of the economic crisis to rebuild consumer confidence that would drive trade.

Competition between regional logistics clusters is harsh. The number of regional governments that wish to promote their region as a logistics hub has grown rapidly during the last decade and not everyone succeeds. From a business point of view, developing successful logistics clusters require mastering the art of simultaneously driving down cost whilst expanding volumes and providing excellent service. From a regional government's perspective, it is about offering the right conditions in which a regional logistics cluster can emerge and advance.

Regional and national governments have an important role in the establishment of logistics clusters. With regard to supporting the establishment of regional logistics clusters, the following aspects may be considered.

*Geographic Location* Some regions and cities have naturally more fortunate geographic locations that allow them to attract major businesses to set up their distribution centres. Proximity to a large number of consumers and a good road-rail-waterborne network are a good argument for attracting logistics flow. Yet, many major urbanised regions are constrained by the lack of space needed for the development of new freight villages. Smaller regions may be better equipped to establish themselves as logistics hubs. Zaragoza in Spanish region of Aragon is a primary example of a smaller region that has successfully established itself as a logistics hub. Located within 3 h drive from the economic centres of Madrid, Barcelona and Bilbao, Zaragoza is now also a major centre for logistics and supply chain management. The frequency of rail and road connections (as well as waterborne and air connections where relevant) is a crucial factor for attracting a critical volume of goods through a logistics cluster. There are numerous examples of struggling terminal operators across Europe and other parts of the world where the volumes are insufficient to provide frequent connections to important destinations in the wider catchment area.

*Land Availability* Global businesses in search of new locations for their logistics facilities view the availability of land as a crucial argument for establishment. Building a logistics hub requires major investment and the possibility for future expansion is essential. When the Swedish furniture maker IKEA built its largest European distribution centre in Dortmund, Germany, it bought the 110 ha industrial estate in several steps. The former coal and steel industry site had been used for carbon and coke reserve until IKEA arrived. The rail connections could easily be built since the former mine rail tracks were already available when IKEA arrived in 2001. The company opened its first warehouse in the area in 2003 and purchased the majority of the site in 2005 (Logistics Location Dortmund 2015). The distribution centre is currently used to serve the entire continent with the fast moving product lines, as well as for all shipments in the nearby area.

*Competence and Education* In competition between logistics clusters, availability of competence and training is a crucial factor. In particular with logistics and supply chain management taking a more prominent role in board rooms, regions that focus on competence centres and education have an advantage. Supply chain management requires educated managers able to operate complex transport and inventory holding networks. Spain/Aragon is a good example with its Zaragoza Logistics Center, which also partners with the MIT. Dinalog in the Netherlands was established as a platform for joint projects between businesses and the academia. It also includes an SME Knowledge Centre, focusing on small and medium sized enterprises that often have limited access to competent logistics staff in-house. Other centres, such as CLOSER in Sweden and HOLM in Germany have emerged during recent years. These platforms are usual based on partnerships between public and private funding and development.

*Sustainability Requirements and Access Restrictions* Government regulations on issues such as noise and environmental impact drive the choice of businesses to establish their logistics facilities. DHL, a major global logistics company, decided to move its European hub from Brussels in Belgium to Leipzig in Germany after it failed to agree with the authorities on night flights. Besides being able to operate around the clock in Leipzig, the German location is also closer to the emerging markets in Eastern Europe and Asia (Deutsche Welle 2008). Clearly, government policies and decisions in such situations are far from straightforward and will likely cause controversy irrespective of the outcome. An in-depth impact assessment considering the economic, environmental and social consequences for the region could help the authorities and policy makers to take a solidly justified decision.

### 3.3 Logistics Excellence on a National Level

Trade and international logistics are both a driver and a result of globalisation. Cheaper transport, larger and more efficient deep-sea ships have made global production and consumption possible. At the same time breaking down of trade barriers has made economically viable to trade globally. As long as transport becomes more efficient and global trade become freer, growth in the logistics sector is likely to continue. At the same time, a favourable geographical position along main trade routes, e.g. between China and Europe, is in itself no guarantee that a country or region would outperform its neighbours with regard to attracting major goods flows through its ports and logistics clusters.

National governments have in the last decade put a clearer focus on creating a favourable environment to benefit from global trade growth. For example, the Netherlands has selected logistics as one of nine top sectors where the country excels globally and that are government priority (Government of the Netherlands 2015). Through such a prioritisation, the government intends to make considerable investments in innovation in the sector, as well as to collaborate with businesses on a broad scale. In 2011, Top Sector Logistics set out the ambition to ensure that by 2020 the Netherlands will occupy an international top position in three areas: handling goods flows, as a chain coordinator of national and international logistics activities, and as a country with an attractive innovation and business climate for the shipping and logistics industries.

In a similar manner national governments around the world have established master plans and strategies to target the various aspects that jointly make up a coherent foundation for logistics excellence. Notably, in many cases, regional development banks have supported the establishment of such plans, e.g. in the case of Thailand.

The World Bank has since 2007 published a Logistics Performance Index that compares countries on six elements:

*Customs*—the efficiency of customs and border clearance
*Infrastructure*—the quality of trade and transport infrastructure
*Quality of logistics services*—the competence and quality of logistics services—trucking, forwarding, and customs brokerage
*Ease of arranging shipments*—the ease of arranging competitively priced shipments
*Tracking and tracing*—the ability to track and trace consignments
*Timeliness*—the frequency with which shipments reach consignees within scheduled or expected delivery times.

The first two elements fall mainly under the public domain as they depend on policy regulations and government efficiency, whereas the latter three belong primarily to the business domain. The quality of logistics services covers competence and training that is to a large degree but not solely the public sector responsibility in most countries.

According to the most recent survey, Germany, the Netherlands, Belgium, the United Kingdom and Singapore are the top five highest performing countries in the world (World Bank 2014).

Similar indicators and indexes have been developed by other organisations, such as Transport Intelligence, providing complementary information on national logistics performance. The six elements of the Logistics Performance Index are becoming increasingly important for international trade in many countries in Africa, South America and Eastern Europe (Martía et al. 2014). The media are often keen on rankings and media pressure, governments are called upon to propose solutions to reach higher positions in future surveys.

### 3.3.1 Strategic Role of the Public Sector

On a national and trans-national level, governments have a central role in helping the logistics sector flourish. Some of the actions that governments can take include the following.

*Increasing the Profile of Logistics* Various approaches have been taken to raise the profile of logistics. In a number of European countries logistics advisory boards consisting of industry representatives have been established by ministries of transport or economic affairs to provide strategic advice to national governments on logistics policy. One of the drivers for such advisory boards is the fact that transport policy has traditionally been modally oriented: transport modes such as rail or road have developed in silos whereas logistics requires a more holistic view of the entire transport system. The Netherlands' choice to make logistics a top national priority was discussed above. Interestingly, the Dutch approach appreciates the fact that logistics is not only about efficiency and cost reduction but includes also new value added services. For example supply chain finance is an area that has not received sufficient attention, although inventory holding cost is a major issue in supply chains. In particular, small and medium size enterprises may struggle as their bargaining power is limited in supply chains. Through a closer partnering with the private sector, the Netherlands has been able to advance on innovative in areas such as this.

*Focusing on International Connectivity* While countries are keen to improve their ranking in international lists, such as the Logistics Performance Index, infrastructure investment decisions tend to be more influenced by domestic and local priorities. A rail and road network that links up major cities in a country often receives more attention from the media and politicians than connections with neighbouring countries. At the same time, cross-border bottlenecks are a major cause of disruptions in logistics chains. In the European Union, the TEN-T network aspires to establish cross-border corridors covering the continent. Although the programme also includes co-financing from the European Union, richer economies must bear the main investment burden nationally. Projects such as SuperGreen and SWIFTLY Green have examined best practices and performance indicators related transport corridor management and could inspire national governments in their efforts to improve international connectivity. Public–private partnerships are also widely used to fund transport infrastructure, in particular road construction and maintenance.

*National Single Window* Governments collect various kinds of information about international shipments, e.g. customs and taxation, veterinary and health data, general freight and transport statistics etc. Different national authorities require different information for their purposes—even though often the same information is requested from multiple government agencies. The internet and cloud computing enable major simplification of reporting to authorities: information could in theory only be inserted once through a portal ("single window") and be extracted by various agencies depending on their needs and rights to access data. In practice, the development is still in early stages. On a European level, the e-Freight initiative has been proposed. In the Netherlands, NLIP (Neutral Logistics Information Portal) has been established.

## 4 Recommendations for Further Development and Research

This chapter has examined some of the challenges that the logistics sector is facing and that new modes of collaboration between public authorities and private companies can help to address. In particular, the role of the public sector has been discussed, given that it has received relatively little attention thus far. Although initiatives are on the way across the world locally, regionally and nationally, further research and development is still needed, including in the following areas:

*Data on Logistics Movements* Most cities in Europe have poor data on freight movements, i.e. what is moved by whom, when, where and by what means (European Commission 2013). As a consequence, it will be difficult to manage traffic flows in cities. On longer distances a number of European countries have advanced freight models in place to support the development of transport infrastructure, but even there further development is needed to harmonise the approaches across the continent. This makes it difficult to compare policy measures, for example to estimate the true cost of congestion to the society (Vierth 2015). Where data on vehicle movements are collected, the public authorities could consider making it publicly available ("open data") to allow traffic management and other services to be developed by companies. Public authorities will also need to consider the emergence of new data sources, such as derived from mobile phone movements or from social media updates. A smarter use of this "big data" will enable more efficient logistics, less congestion, lower emissions and better air quality. One of the difficulties with better usage of such data relates to privacy: individuals and companies must feel secure that the data they create is not misused. A legal framework is needed to provide that security and to enable the usage of data on an aggregated level for planning and service provision purposes. Establishing such a legal framework is a complex task, not only due to the rapid technical development of information, communication and mobile technologies but also due to the cultural differences across Europe regarding privacy issues.

*Innovative Public Procurement Schemes* The public sector's ability to promote societal goals through public procurement should be explored further. Traditionally cost has been the key factor for selecting providers of goods and services. Yet, a fresh look may be needed in order to better promote the societal objectives, such as environmental or social sustainability. For example, would it be justified to procure service trucks that pollute less but cost more? Innovative public procurement may entail procurement of products or services that are already on the market (e.g. less polluting or electric trucks) but it may also focus on new product development (i.e. products or services that are not readily available on the market as yet). An example of the latter are innovation competitions where an organisation defines a clear objective—a challenge or problem—and calls upon the market actors to come up with solutions. In the United States, NASA is a government agency that has used innovation competitions successfully in its work. The US government agencies publish their challenge competitions on a website (http://www.challenge.gov/list/). The European Commission organises prize competitions within the Horizon 2020 programme. Innovative public procurement is by no means a simple tool and requires a considerable mindshift among public employees. The legal framework may also make its application difficult.

*Growth of E-commerce* While still a relatively small share of the overall retail sale, e-commerce grows annually in double digit figures in many European countries. This poses a challenge to logistics operators that have to cope with rapidly expanding volumes. New models of delivery, such self-service post boxes, have emerged across Europe. Yet, the impact of e-commerce on spatial planning needs further exploration. It could, for example, be envisaged that self-service kiosks can be built at metro stations or other public spaces maintained by the local authority. The Cross-border dimension of e-commerce also need further work. Apart from the giants, such as Amazon or Zalando, smaller and niche web shops have emerged. Many of the online boutiques offer international delivery in the spirit of the common European market. While this mostly benefits consumers, it has also brought to the forefront the multitude of national rules on consumer protection. International harmonisation may be needed to facilitate the development.

## 5 Conclusions

Governments in cities, regions and countries have stepped up their efforts to achieve a more coherent policy on logistics. This has opened up opportunities for new collaboration modalities between logistics companies and authorities. Public authorities are exposed to new expectations, where they can no longer act solely as regulators. Instead, they must find new ways to partner with businesses while maintaining impartiality. This is by no means a simple equation. The private sector will also need to adapt to be able to benefit from these new partnership opportunities. Finding the time and other resources to commit to research and innovation projects or an urban logistics strategy may not be perceived as a priority in the short term but could benefit companies in the long run.

New models of governance and partnering between the public and private agents are likely to emerge over time. Defining common objectives such as maximising the efficiency of the transport system while minimising environmental impact might be a good starting point. Still, a number of complexities remain. Financial viability and risk sharing is one. This chapter has focused on loose forms of public–private partnerships, i.e. those not involving construction of transport infrastructure, where risk sharing is often the crucial point for a success of a project. Yet, even in non-construction partnerships financial incentives may be needed to stimulate a shift towards more sustainable logistics solutions. A second complexity relates to the political nature of the public sector: as elections could lead to shift in political priorities, there is a risk that freight issues are neglected.

There appears also to be a notable need for further development of competence in the field logistics among public sector officials. Especially on the local level where decisions on procurement are made, many smaller local authorities could reduce their cost and improve service by improving their logistics competences. Also, on a national level, transport policies have traditionally developed in modal silos. A coherent logistics policy would require a cross-modal approach with further inputs from non-transport sectors, such as customs and information and communication technologies. This is by far from simple to achieve in practice but attempts to bring together various stakeholders from the entire logistics sector (as well as other disciplines) are essential to move forward. This chapter has for the purpose of simplicity distinguished between urban, regional and national governments. In practice, the levels intertwine: a country's quality of logistics sector depends also on regional and local initiatives. The European Union has for example included urban nodes in its TEN-T programme, although main focus is on cross-border connections. A coherent logistics policy must consider all levels of government and their interplay.

## References


Baker CR (2003) Investigating Enron as a public private partnership. Account Audit Account J 16 (3):446–466

Bovaird T (2004) Public-private partnerships: from contested concepts to prevalent practice. Int Rev Admin Sci 70(2):199–215

Bramwell B, Lane B (2000) Collaboration and partnerships in tourism planning. In: Bramwell B, Lane B (eds) Tourism collaboration and partnerships: politics, practice and sustainability. Channel View Publications, Clevedon, pp 1–19

Broadbent J, Guthrie J (1992) Changes in the public sector: a review of recent 'alternative' accounting research. Account Audit Account J 5(2):3–31

Buhr H (2006) Ett smitande botemedel? [An infective cure?]. In: Mörth U, Sahlin-Andersson K (eds) Privatoffentliga partnerskap: styrning utan hierarkier och tvång. SNS Förlag, Stockholm, pp 57–76

Caiazzo F, Ashok A, Waitz IA, Yim SHL, Barrett SRH (2013) Air pollution and early deaths in the United States. Part I: quantifying the impact of major sectors in 2005. Atmos Environ 79:198–208

Council of Supply Chain Management Professionals (2015) Supply chain management definitions [Online] 29 Jan 2015. http://cscmp.org/about-us/supply-chain-management-definitions

Deutsche Welle (2008) Logistics giant DHL opens new European Hub in Leipzig [Online] [15 Feb 2015]. http://www.dw.de/logistics-giant-dhl-opens-new-european-hub-in-leipzig/a-3361016

European Commission (2007) Freight transport logistics action plan. COM (2007) 607 final of 18 October 2007

European Commission (2011) White paper 'roadmap to a single European transport area—towards a competitive and resource-efficient transport system'. COM (2011) 144 final of 28 March 2011

European Commission (2013) A call for action on urban logistics. SWD (2013) 524 final of 17 December 2013

European Commission (2015) Public procurement in a nutshell [Online] [10 Feb 2015]. http://ec.europa.eu/trade/policy/accessing-markets/public-procurement/

Fischer K, Jungbecker A, Alfen HW (2006) The emergence of PPP task forces and their influence on project delivery in Germany. Int J Proj Manage 24(7):539–547

FORS (2015) Fleet operator recognition scheme [Online] [30 Jan 2015]. http://www.tfl.gov.uk/corporate/terms-and-conditions/fors

Government of the Netherlands (2015) Investing in top sectors [Online] [4 Feb 2015]. http://www.government.nl/issues/entrepreneurship-and-innovation/investing-in-top-sectors

Grimsey D, Lewis MK (2007) Public private partnerships: the worldwide revolution in infrastructure provision and project finance. Edward Elgar, Cheltenham

Hodge GA (2004) The risky business of public-private partnerships. Aust J Publ Admin 63 (4):37–49

Jacobsson B, Sundström G (2001) Resultat utan lärande? Erfarenheter av tre decennier av resultatstyrning [Result without learning? Three decades of experience of goal oriented management]. Stockholm Centre for Organizational Research, Stockholm

Logistics Location Dortmund (2015) Ellinghausen [Online] [11 Feb 2015]. http://www.logistics-dortmund.de/en/flaechen/ellinghausen.jsp

Martía L, Puertasa R, García L (2014) The importance of the logistics performance index in international trade. Appl Econ 46(24):2982–2992

Peters BG (1998) 'With a little help from our friends': public-private partnerships as institutions and instruments. In: Pierre J (ed) Partnerships in urban governance: European and American experience. Macmillan Press, Basingstoke, pp 11–33

PWC (2014) Has trade growth become disconnected from GDP growth? [Online] [2 Feb 2015]. http://pwc.blogs.com/economics_in_business/2014/12/has-trade-growth-become-disconnected-from-gdp-growth.html

Sandebring A (2006) Att organisera privat-offentlig samverkan [To organise private-public collaboration]. Licentiate dissertation. Stockholm School of Economics, Stockholm

Shaoul J (2002) A financial appraisal of the London underground public-private partnership. Publ Money Manage 22(2):53–60

Sheffi Y (2012) Logistics clusters: delivering value and driving growth. MIT Press, Cambridge, MA

Taniguchi E (2012) Concept and best practices of city logistics. International Transport Forum, Leipzig

Vierth I (2015) Samhällsekonomiska kalkyler för godstransportrelaterade åtgärder i Sverige och andra länder [Socioeconomic cost-benefit analysis for freight transport in Sweden and other countries]. Presentation at Transportforum, Linköping

World Bank (2014) Logistics performance index [Online] [9 Feb 2015]. http://lpi.worldbank.org/report

World Health Organization (2011) Burden of disease from environmental noise. World Health Organization, Copenhagen

# Towards a Harmonized Framework for Calculating Logistics Carbon Footprint

**Alan Lewis**

**Abstract** Internal and external pressures on the various stakeholders in the transportation of goods have resulted in a wide range of operational choices and a proliferation in the way in which their success can be assessed. Environmental impacts form only one part of the decision making process, alongside cost, promptness, reliability, safety etc. However, having recognised the place of the environment, and particularly the carbon footprint, within such decisions it is crucial to have a reliable and consistent method as an input to the process. Such a method must be harmonized to allow comparable calculations to be made for the wide range of modes, vehicle types and operational characteristics that may be used along current global supply chains. It must also be acceptable in terms of input required, accuracy and comprehension to those who use it, including policy makers who set global targets and monitor overall progress. Significant progress has been made to develop and start to implement such a harmonized methodology framework from a highly fragmented starting point, although much remains to be done. This paper reflects the work to date and the approach to the next steps that are already underway.

## 1 Motivation

Freight transport is an important economic sector and freight movement is increasing, fuelled by economic growth, globalization of markets and urbanization. Global trade is changing due to the expansion of emerging markets and their integration into the global system. This is affecting the typical length and complexity of global supply chains, which in turn contributes to the negative impacts of transport, including its carbon footprint.

By 2050, surface growth freight transport is projected to range from 40 to 124 % in the OECD countries and between 100 and 430 % in the non-OECD economies. Freight related to international trade is estimated to grow by 350 % by 2050

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according to preliminary results from the ITF Transport outlook 2014 (International Transport Forum 2013). Freight logistics as a sector is also responsible for 5.5 % of global $CO_2$ emissions (World Economic Forum/Accenture 2009).

Transport companies have at their disposal a range of possible modes by which to transport goods. Increasingly attention must go to "green" solutions both to improve image and to increase efficiency for the business, but also because of legal pressures. Different countries already have their own legislation or specific requirements in respect to $CO_2$ accountancy; for example the French government requires specific $CO_2$ reporting for transport services (both passenger and freight) starting, finishing or passing through France, through a decree that came into force in October 2013 (Arrêté du 10 avril 2012). Variations in technology and working practices are common. A range of initiatives to calculate the emissions from freight transport have been developed: sometimes originating on a modal basis, at other times by region; some companies have felt the need to create their own systems, so adding to the number of methods and tools in use and suspicion as to the basis of individual calculations.

There is considerable variability among existing freight emissions methodologies and their recommended databases. For example, different methodologies often recommend using different emission factors, both in terms of emissions included, values and units. Indeed, having such a wide range of calculation methods and tools available makes direct comparison of the results, even for the simplest supply chains, impossible. The multiplicity of tools and methodologies makes the choice difficult and impacts (perceived) accuracy of calculations, especially in case of complex multi-modal supply chains. As a consequence there is often no confidence or clarity in the results obtained. Uncertainty rules: what is the best low carbon footprint and business solution? All these factors are at the heart of the need for harmonization. Internationally applicable guidelines, supporting tools, data quality standards and methods for the calculation of transport related emissions therefore need to be developed and implemented now. It is not just an EU challenge: it is a global challenge, but solutions go down to local level with city distribution contributing 20 % or more to total emissions.

### *1.1 The Broader Green Freight Agenda*

The underlying potential performance of the freight sector is influenced by the interaction of three components: the transport system (i.e. infrastructure and policies), freight equipment (i.e. vehicles and vessels) and freight operations (e.g. shipper, 3PL and carrier logistics decisions). In an ideal world, the freight sector will be supported by a quality transport system, consisting of quality infrastructure and connectivity within and between modes with supporting policy and regulatory frameworks; optimized freight movement including sector-wide adoption of logistics solutions that maximize load factors and optimize the routing and scheduling of freight flows; and use of efficient vehicles and vessels via sector-wide adoption of technologies and operational strategies that offer greater efficiencies and emission reductions.

With these in place making good policy, strategic and operational decisions is easier, but not guaranteed; without them it gets much more difficult.

The freight sector is complex and fragmented and therefore the challenge to achieve a near zero carbon footprint must be tackled from different directions that involve a multitude of stakeholders. The key actors within the global freight supply chain are those directly involved in the production, movement or receipt of goods (shippers, logistics providers (LSPs), freight forwarders, carriers, and customers/receivers) and those who set the wider context and hence influence different aspects and patterns in the freight sector (government, civil society [including non-governmental organizations, universities/academics and research institutes] and financing institutions/development agencies).

Views differ on whether this market pressure cascades to different players in the global freight supply chain.

Carriers measure their emissions, analyze their performance, prioritize technologies and other actions to improve their performance, implement them, and measure results in terms of emissions, fuel and cost savings.

Shippers/customers can reduce the emissions from transported products/goods by selecting efficient carriers and helping them to improve efficiency. They need carriers to report their emissions (through an independent body or have data externally validated by some other means) in a way that permits benchmarking and the use of emissions as a criterion to select carriers (together with other selection criteria, most commonly costs, quality and time/reliability).

The complexity and fragmentation within modern supply chains can make it hard to see the actions that are needed to offset the impact of both the overall growth in freight transport and supply chain lengths by increasing efficiency of the transport functions that are essential to meet economic demands. At the global level, multinational firms are under growing pressure from shareholders, customers, and government to reduce their carbon footprint and other adverse impacts from the movement of goods and materials worldwide, as witnessed by publication of corporate carbon reduction targets. At the local level, freight transport can be responsible for far greater emissions and more traffic accidents than passenger vehicles.

To create a common view of what is needed to achieve the desired transformational change and emission reductions at scale, Smart Freight Centre has developed the Smart Freight Global Framework for Action (Fig. 1) (Smart Freight Global Framework for Action 2015). The Smart Freight Global Framework for Action starts with leadership from government, the private sector and civil society; uses programs and the removal of barriers for the uptake of solutions at scale; and is supported by partnerships.

Beyond creating a common view, this framework can be used to spur and guide action to accelerate the uptake of smart freight solutions by industry. The hierarchy is based around the four key elements of leadership, partnerships, programs and technologies and actions (Fig. 1).

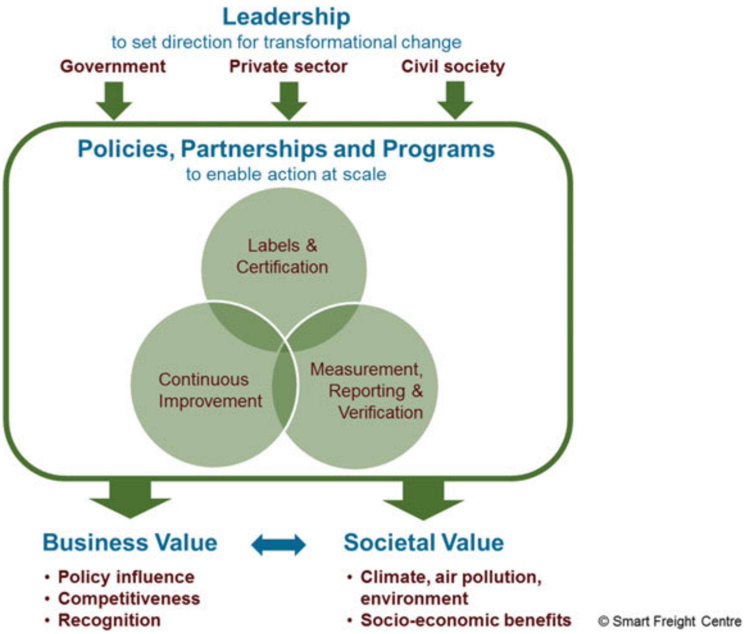


**Fig. 1** Smart Freight Global Framework for Action

The work of Smart Freight Centre through the Global Logistics Emissions Council (GLEC) on harmonization of methodologies is just one supporting part of this.

## *1.2 Support for Monitoring, Reporting and Verification*

In order for such policy-based and operational targets to be meaningful there needs to be a well-understood and accepted method for calculating comparable emissions values leading to a clear baseline, and a range of mechanisms available to those involved in shipping and transporting goods by which emissions might be reduced. A realization of potential gains in efficiency of supply chains requires the identification of best practice and a comparison of different approaches across modes, routings and company structures. Such a comparison is only possible if comparable analysis methods are applied, and with so many transport operations and supply chains being at the global level, it is important that the methods applied for the calculation of emissions need to be comparable not only on a national, but on an international basis. This is fundamental for those involved in implementing choices as they need to be able to apply their decisions in a consistent manner across their global supply chains.

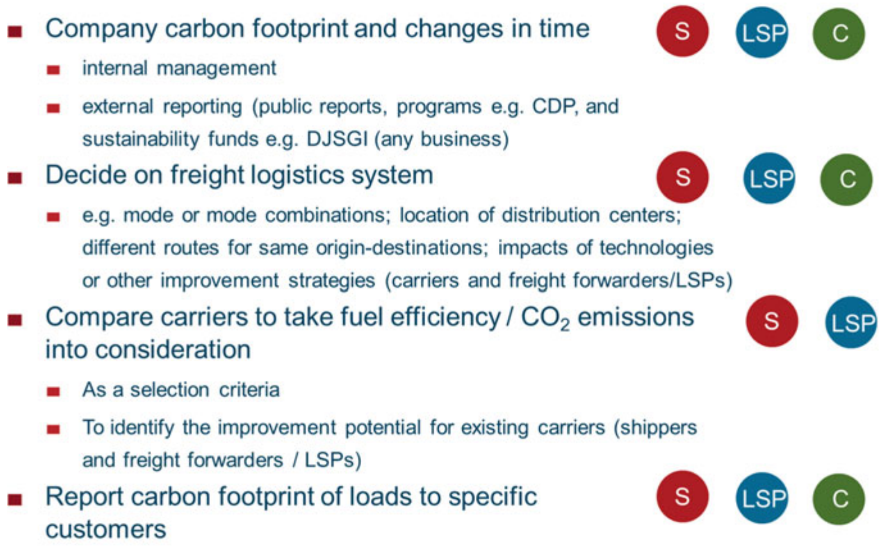


**Fig. 2** GLEC decision support framework

Some companies have included fuel efficiency and carbon footprint as part of their purchase decision-making in relation to freight, but this is not widely applied and the weight applied to it alongside other procurement factors is uncertain (Fig. 2); however, the main driver for both procurement and efficiency improvements is cost saving leaving the two issues as interlinked.

### *1.3 Global Dimension*

Despite proven economic drivers, potential for improvement and documented opportunities, we have not seen a change at a global scale yet. An important underlying reason for this is the complexity and fragmentation of the freight sector spanning different modes and regions. Wide application of smart freight principles transcends the influence sphere of individual countries and companies. Momentum for smarter freight is growing, witnessed by growing government and industry initiatives, technology innovation and research programs; however, as a whole, the support frameworks that are needed for a greener and more efficient freight sector are still fragmented and often disconnected. Individual companies, governments, civil society cannot address this challenge alone: coordination and collaboration is key.

Given this growing pressure it is not surprising that there was an increase in activity in the area of carbon footprint calculation in recent years. Initially this resulted in an increase in the amount of uncoordinated activity as different organisations, operating in different sectors, each put their mind to 'their bit' of the problem, often without knowledge or understanding of the efforts of others.

However, over time understanding has grown that the level of fragmentation that existed was part of the problem, and hence unsustainable. The following sections provide a brief review of recent structural and technical progress towards a harmonized approach for carbon footprint calculation in the future. It finishes with an assessment of the challenges that remain and provides some answers as to how they may be met.

## 2 Methodologies

Before embarking into the detail of who was or is doing what and why in the field of carbon footprint methodologies, it is first worth introducing a hierarchy of four different levels: Programs, Methodologies, Tools and Databases.[1] This hierarchy is shown in Fig. 3.

Programs represent the highest level of the hierarchy, and consist of guidelines describing what activities should be accounted, which emissions to track, as well as how they should be reported. A program need not specify the actual method used to perform the calculations, but may provide one or more approved methodologies. The "Corporate Accounting and Reporting Standard" published by the GHG Protocol or the USEPA SmartWay Program are good examples.

Methodologies represent the next level in the hierarchy, and specify the processes by which emissions should be calculated. A single program might have a number of appropriate methodologies that could be used, and conversely a single methodology could be appropriate to use in a number of different programs. The GHG Protocol, for example, allows for two different methodologies to calculate emissions from mobile sources: fuel-based and distance based. The fuel-based

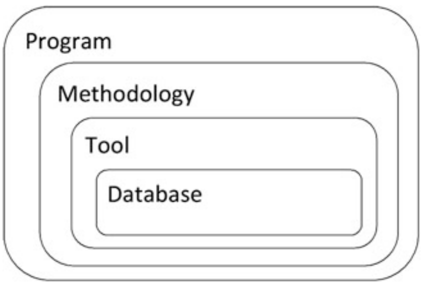


**Fig. 3** A hierarchy to discuss freight environmental emissions. *Source*: Blanco (2014)

[1] This section is taken from Blanco E.E., GLEC Strategy Annex (Blanco 2014), with author authorization.

methodology, in turn, is shared with the Intergovernmental Panel on Climate (IPCC) methodology guidelines.

Tools represent the next level of the hierarchy and represent a specific implementation of a methodology. A tool provides the ability to produce an actual quantifiable value for emissions by implementing a methodology, by encoding well-defined inputs, calculations and external data sources, such as emission factors databases or distance calculations. The GHG Protocol, for example, provides a series of spreadsheets that allow data inputs that are then combined with emission factors from the US Environmental Protection Agency (EPA), UK Department for Environment, Food, and Rural Affairs (Defra) or the IPCC, among others.

Databases represent the final level of the hierarchy and consist of repositories of emissions factors or reference values that are expected to be used within a tool or methodology. Although databases are usually developed and technically specified alongside a specific tool, they often include a set of standard values (e.g. emission factors) or default assumptions that are provided by third parties such as the EPA and Defra.

It is often the case that a "tool" and a "methodology" are intimately linked together since entities working in methodology development (unless academic in nature) are interested in providing tools that help their intended audience apply the methodology, for example NTM and EcoTransIT. Also, using common databases of emission factors across tools, methodologies and programs is an effective way to achieve harmonization.

## 2.1 Research Baseline

By around 2011 the situation arose whereby research projects had been initiated in Europe and the USA to provide a description of the status quo regarding the methodologies current at that time and to provide a way forward for a harmonized approach and a consolidation of efforts. In the USA the work was led by Dr. Edgar Blanco of MIT through a National Cooperative Freight Research Program grant. In Europe the work was conducted under the auspices of the COFRET project, which was part-funded by the European Commission.

The extent of the work that was ongoing at that time was revealed by the initial review conducted by COFRET which identified and reviewed more than 100 potentially relevant methodologies, calculation tools, emission factor databases and other activities or initiatives without claiming to be exhaustive. Following an initial screening process, the 27 items considered to be most relevant and accessible for the subsequent work of COFRET were identified. Some of the most relevant and well-known items included (Table 1):

In addition to these methodologies, tools, databases and other items a number of industry programs that combine various aspects of data collection, calculation and operational improvement were beginning to form using a range of different funding sources and participation models, including the US EPA's Smartway programme,

**Table 1** Key precursor methodologies, tools and databases assessed by COFRET (Auvinen et al. 2011)

| Item name | Strengths according to COFRET (Auvinen et al. 2011) |
|---|---|
| ARTEMIS | Detailed annual emissions database that includes all modes except air. Maneuvering and internal transport also included |
| Bilan Carbone | French approach to calculations on a vehicle level; also offers a tonne kilometre approach |
| DEFRA | Emission factor database for combinations of different vehicle types, fuels and load factors |
| DSLV | Practical guidelines based on EN16258, focus on road transport |
| EcoTransIT World | Includes a detailed and accurate database. Vehicle level |
| GHG protocol | Well structured, widely accepted general approach to corporate/ product level emissions |
| HBEFA | Widely accepted detailed database for road transport, valid for a limited number of countries |
| JEC emission factors | Databases of fuel production (WTT) and point of use (TTW) emissions |
| Map & Guide | Calculation tool that implements EN16258 using HBEFA data |
| NTM | Widely acknowledged member-only calculation tool that aims to cover all logistics operations |
| World Ports Climate Initiative (WPCI) | Widely accepted approach for short sea, deep sea and terminals |

Green Freight Europe, Green Freight Asia, Clean Cargo Working Group, Lean and Green and ECO Stars.

## 2.2 *The Role of Standards*

Working alongside these initiatives, the European Committee for Standardization (CEN) also convened a working group on the topic of carbon footprint of transport and in 2012 CEN published the European norm EN16258: “Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers)”, which is probably still the closest thing to a formal transport chain emission calculation standard at the moment. Many of the European programs and tools have now aligned their methodologies to the broad rules set out in EN 16258. However, as will be explained next, even with the significant step forward brought by the publication of EN16258 there is still much more required for a truly harmonized approach.

Despite all these efforts and the identified need for harmonization, various gaps were found to exist when it comes to the calculation of transport chain $CO_2$ emissions. In the context of the most commonly cited and promising existing formal standards in this area ISO 14064/14067 and the GHG Protocol do not focus on transport directly. As a consequence, their regulations about the accounting of transport are not sufficiently specific for unambiguous approaches to be taken within the overall guidance. EN 16258 focuses on transport and logistics and introduced some very valuable concepts and specifications on how carbon footprint calculations for freight transport chains should be specified. However, it includes four different levels of accuracy which can all be considered as compliant with the standard, but which are not directly comparable with each other, meaning that compliance with the standard does not guarantee direct comparisons to support corporate decision making. Furthermore, EN 16258 lacks coverage of terminals and warehouses.

## 2.3 Practical Application

Because of the inherent differences between transport modes and the characteristics of different types of goods, it is apparent that as part of a harmonized solution it will not be possible to accommodate every single subtlety that comes from the wide range of factors that influence reporting requirements and energy consumption: e.g. local legislation, mode-specific working practices, company specific data handling, varying climate conditions throughout a year etc. However, research and consultation has led to a framework that has the potential to provide a much more closely aligned calculation framework. The improvements suggested as part of the future framework need to be practical and pragmatic in order to ensure a high user acceptance. Any emission calculation method which is developed to become a global standard needs a high level of user acceptance as there is currently no structure to enforce or verify its use. As a consequence, any further development of a $CO_2$ emission calculation method needs to bridge the fragile trade-off between simplicity, accuracy and flexibility (Fig. 4).

## 2.4 Bases of Calculation

When calculating $CO_2$ emissions it is important that the entire transport chain from an item's point of production to its place of consumption or further processing is covered. This item, i.e. a unit of freight, can be a product, a package, a pallet, bulk product (measured in tonnes) or a container. Such an approach to $CO_2$ emission calculation allows computation of emissions from door-to-door, thus allowing the shipper a choice in the selection of their transport solutions. Furthermore, product level door-to-door emission computations also allows benchmarking of supply chains and labelling of the products in respect to $CO_2$ emissions coming out from transport and logistics operations on the way from production to consumption. In complex transport supply chains, the full chain consists of more than one consecutive transport, terminal or warehouse operation.

The COFRET project introduced the notion of Transport Chain Element (TCE) as a modular and independent element within the transport chain to be used as the

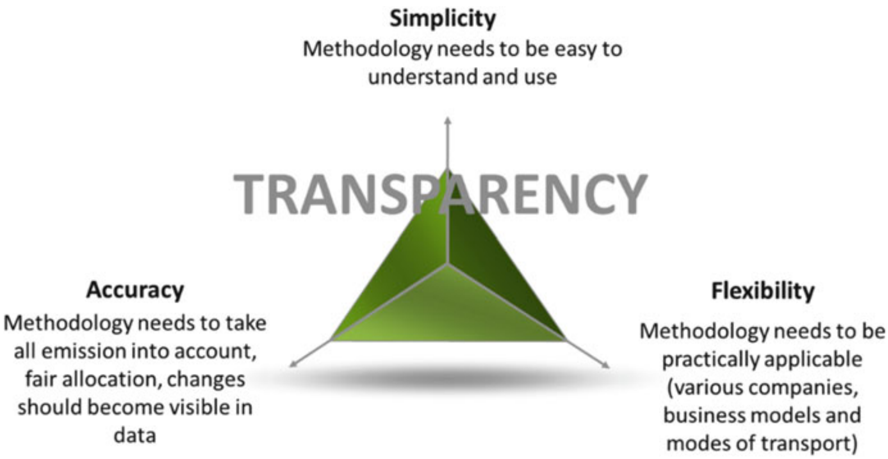


**Fig. 4** Diekmann, COFRET (Auvinen et al. 2013)

basis for step-by-step calculations. Figure 5 presents an example of a transport chain composed of TCEs. It is worth noting that not only transport operations are considered as TCEs, but terminal and warehousing operations are also treated as separate TCEs. The resulting $CO_2$ emissions at the product level are, therefore, the sum of the emissions resulting from the TCEs that constitute the full transport chain.

The division of any transport chain into a number of sequential TCEs greatly simplifies the effort necessary to compute chain-level emissions. Any transport chain can be composed of a limited number of TCEs, such that the building blocks (TCEs) can be used and reused in any arbitrary situation. It also simplifies conformity to the European standard, EN 16258, which is written to be applied at the level of individual transport-related TCEs.

$CO_2$ emission calculation at the product level presents an intrinsic challenge related to data availability and different perspectives along the transport chain. Product-level emission calculation requires information on $CO_2$ emission from all constituent transport chain elements. Furthermore, product-level emissions are related to the shipper or consignees, who send or receive the products, while a number of transport service providers conduct the relevant transport activities. Thus, in many cases it is difficult if not impossible for the shipper or consignee to determine total product-level emissions accurately, because there is no complete information on SCE level emissions.

EN 16258 does not provide a full solution in this case, because it prescribes how $CO_2$ emissions should be computed within an individual transport-related TCE, rather than joining them to form a supply chain. As a consequence, EN 16258 does not provide the means for information exchange along the transport chain: it lacks specifications and prescriptions on information exchange and data requirements.

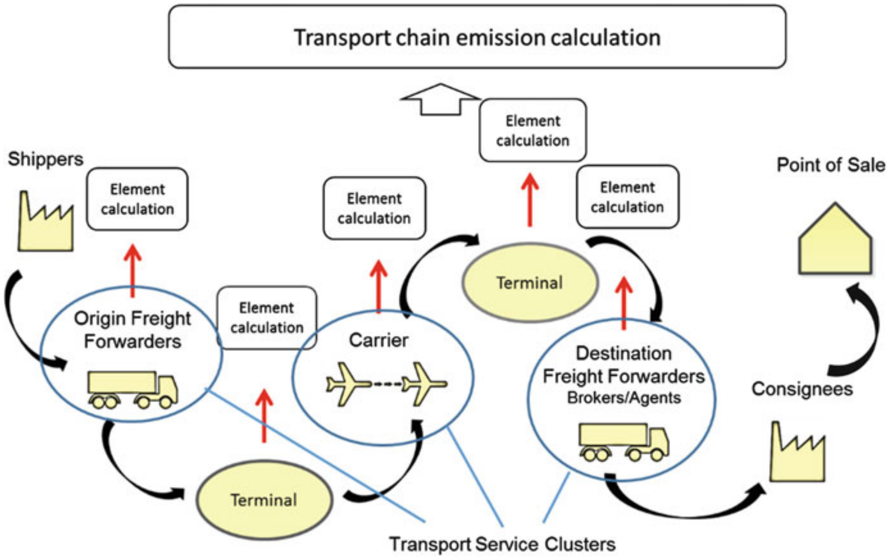


**Fig. 5** Division of a transport chain into a number of sequential transport chain elements; Ehrler (Auvinen et al. 2013); modified for GLEC

The absence of such a prescription or guidance makes it impossible to compute the chain-level door-to-door emissions in a standardized way. Moreover, chain level emission computation would require that each individual TCE be dealt with using the same methodology. Consequently, there needs to be a prescription for the type of information that should be exchanged between supply chain partners. Only if all supply chain partners compute $CO_2$ emissions in the way the required by standard and only in case of this information being pushed along the chain, and only if node TCEs can be included in the calculation in a standardized way, can the shipment level door-to-door emissions be considered to be computed in a harmonized way—hence the need for an aligned calculation framework.

The main methodologies in this area based on two broad foundations.

Fuel-based methodologies use actual fuel consumption data as the basis for estimating the associated emissions, based on the content of the fuel and assumptions regarding its combustion. Fuel-based calculation is listed as the methodology of first choice for the GHG Protocol, EN 16258 and serves as the primary methodology for use in the IPCC national emissions inventories. Fuel-based methodologies are the preferred method when historic records are of interest and are by nature backwards looking, relying on the accounting of fuel consumed, and would require assumptions to be made if used for assessing future improvement scenarios.

Activity-based approaches provide a methodology that, while not as accurate for historical emissions of $CO_2$ as fuel based approaches, is very well suited for macro-level planning situations. In activity-based methods some measure of activity, such as vehicle miles travelled or tonne-km moved, are multiplied by a macro-level factor to estimate total emissions.

When developing logistics emissions methodologies, tools or databases, it is important to understand that shippers and carriers have access to different types of activity data with varying degrees of accuracy. The different perspectives determine what is feasible in terms of available data that can be converted into results with the necessary substance behind them. For example, fuel-based methods require knowledge about actual fuel consumption data that is often not available to shippers. Carriers are the ones that can provide fuel consumption information of their operations. However, different carriers keep fuel consumption records at varying degrees of detail: airlines keep accurate records of fuel consumption for every airplane and flight, ocean carriers keep accurate fuel consumption records for full routes while truck carriers may only keep records at the fleet level.

Shippers often have no information on the actual distance traveled by their shipments and so they rely on estimated distances from secondary sources. In contrast carriers decide on the actual path and are the only ones that can provide reliable estimates of true distance traveled. Carriers keep varying degrees of accurate records of loaded and un-loaded distances, often a function of the mode of transportation and the type of service provided (e.g. truckload vs. less-than-truckload).

Shippers know the weight and volume of all shipments via their internal records that describe their products and materials. Carriers, on the other hand, do not always have access to detailed information on the weight or volume of a shipment unless this affects the contract with the shipper. For example, full-truckload shipments often contain unreliable weight or volume data since carriers charge for the distance traveled.

Whenever possible and whenever reliable records are available, it is always better to gather activity data from the stakeholder with the most accurate information as described above. This will vary by mode of transportation and sometimes by geographical region, depending on business practices.

As more precision in calculations requires going within the corporate boundaries of a shipper or carrier, the methodology needs to develop allocation criteria to assign emissions to smaller units of interest such as lanes or shipments. For example, when allocating emissions to shipments, a methodology needs to specify how to calculate emissions for a vehicle as a whole, and then how assign those emissions to each of the shipments it carries. This allocation could be done based on volume, weight, distance, value, or some combination of these. The EN 16258 standard, for example, provides a number of methods for separating emissions from freight and passengers, as well as between shipments on the same vehicle.

The choice of allocation method can have significant impact on calculated emissions. No choice of method will necessarily satisfy all stakeholders perfectly, so a focus on consistency and transparency is recommended. Carrier level precision is often the most appropriate to begin with for truck and rail transportation methodologies, while lane-level precision is suitable for air and water transportation methodologies, as both shippers and carriers will be able to collect and share information at levels that match their business levels of decision-making. As organizations mature, including familiarity and availability of data, higher levels of precision could be considered including more specificity on allocation approaches. In any case, allocations that are dependent on arbitrary choices such as which customer is delivered to first in a route should be avoided.

Lastly, when assessing the precision of a methodology, it is important to recognize that there is a temporal and geographical element to transportation, especially with regard to road and waterborne modes. A methodology that may be considered to be of high level of precision for a particular geographical region (e.g. NTM in Europe) may yield very low precision estimates if used in another regions due to variations on operating conditions and underlying data assumptions (e.g. congestion in Mexico). Also, due to peaks and troughs of asset utilization and weather conditions, emission calculations may vary throughout the year.

## 3 Development of a Level Playing Field: A Global Harmonized Framework

Recent work on a harmonized framework has progressed through two interlinked mechanisms.

Firstly, the nucleus of the group of logistics companies and industry led/backed initiatives that formed the COFRET Advisory Board, together with the Smart Freight Centre (SFC) initiated the Global Logistics Emissions Council (GLEC). The GLEC has been expanded to a global level with additional companies and experts, SmartWay, Green Freight Asia and global industry associations. GLEC aims to achieve:

A common industry vision statement regarding methodologies and broader green freight; globally harmonized methodologies (Global Framework for Logistics Methodologies) for measurement and reporting of emissions from freight movement covering all modes, transfers and regions; alignment of industry led/backed initiatives across modes and global regions; active engagement and communication with the entire global freight sector and other key stakeholders, e.g. government, scientific/research institutes, NGOs, development agencies.

Smart Freight Centre, a global non-profit organization with a mission to "support and incentivize the global freight sector to adopt solutions that reduce emissions intensity and improve fuel efficiency and take these to scale through a global framework for action", has been given the mandate and resources to lead and coordinate the work of GLEC.

SFC's role is to lead the development and implementation of a strategy in support of the group's objectives; organize and facilitate meetings of the group and cooperation between its members; engage with the global freight sector and other key stakeholders relevant to this group, which includes positioning the work of the GLEC within a wider portfolio of programs aimed at increasing freight sector efficiency.

Secondly, the issue of standardization was at the forefront of the COFRET project. Building on the CEN project liaison status granted to COFRET, links were sought with the ISO central secretariat. As a result of these links the ISO secretariat encouraged the DIN to develop, in partnership with COFRET, a proposal for an International Workshop Agreement (IWA) on the topic of "Quantification of $CO_2$ Emissions of Freight".

The overall purpose of this approach has been to obtain consensus through wide stakeholder agreement on the scope of a future methodology framework backed up by an action plan for harmonization towards a practical framework applicable across sectors and regions (Fig. 6).

The ISO IWA "International harmonized method(s) for a coherent quantification of $CO_2$e emissions of freight transport" was published in January 2015 as ISO IWA No. 16 (ISO 2015) and states: "A continued close cooperation between the GLEC and global standard issuing organisations, e.g. GHG Protocol and ISO is recommended to further work on this emission calculation standardization, thus enabling a swift and effective next step towards the optimization of transport chains' efficiency and related reduced transport emissions on a global scale".

### *3.1 The GLEC Global Framework for Logistics Methodologies*

The centerpiece of the GLEC is the development of a Global Framework for Logistics Methodologies as well as ensuring wide acceptance and taking its application to scale. An initial version of this framework, referred to as the Base GLEC framework, was published in January 2015 and opened to public consultation as part of ongoing work towards a revised version due in late 2015/early 2016.

The Base GLEC framework has identified existing methodologies that have been developed to have a similar basis for their calculations and are widely used within the global logistics industry. These have been nominated as the starting point for the aligned methodology framework (Table 2).

Because the GLEC framework is based primarily on this existing practice the base methodologies have been developed independently and are at different levels of maturity. As the GLEC framework recognizes an aspiration for change, where needed, to improve comparability along a multi-modal supply chain, it may be that recommendations will be made to help application of the GLEC framework across modes.

The base methodologies within the framework align around the basic principle of identifying the actual amount of fuel needed to carry out a certain amount of work when transporting the goods, i.e. are primarily fuel-based in nature whilst acknowledging the relevant transport activity. This must include the fuel used by

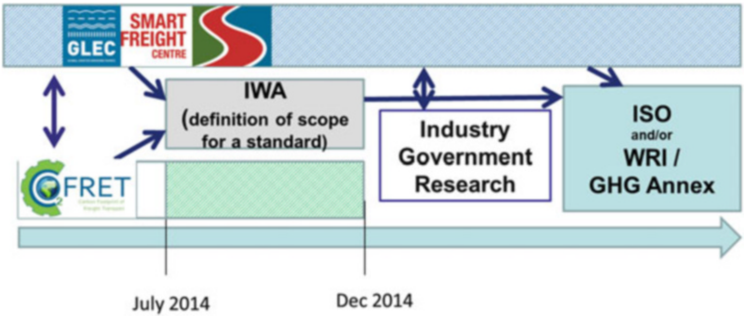


**Fig. 6** Strategy timeline for further methodology harmonization (Final Results Report 2014)

**Table 2** Elements of the base GLEC framework

| Mode | Base methodology per mode | Others considered |
|---|---|---|
| Air | International Air Transport Association (IATA) Recommended Practice 1678 | EN 16528, US SmartWay air module, EU ETS, French Info $CO_2$ |
| Sea, container | Clean Cargo Working Group | EN 16258, Clean Shipping Index Protocols, IMO EEOI |
| Sea, other (bulk, tanker, ferry. . .) | IMO Energy Efficiency Operating Index (EEOI) | EN 16258, Clean Shipping Index Protocols, IMO Energy Efficiency Design Index (EEDI) |
| Road | SmartWay road module<br>EN 16258, at level of transport operator specific values | French Info $CO_2$, EcoTransIT, NTM, Defra, HBEFA |
| Rail | EcoTransIT | EN16258, SmartWay rail module, NTM, French Info $CO_2$ |
| Inland waterways | IMO EEOI | SmartWay steaming module, STREAM, EN 16258 |
| Transhipment centers | Green efforts | Green Logistics, ITEC |

vehicles when they are being repositioned between individual trips and on a round trip basis.

This 'consumption factor' is used as the basis of transferring data between the different players in the supply chain.

Consumption factor = total fuel (energy) consumption divided by the total work done, expressed as distance × mass.

or in scientific notation:

$$Transport\,consumption\,factor = \left(\frac{\Sigma fuel}{\Sigma tonne\,kilometres}\right) \tag{1}$$

The emissions resulting from combustion of the fuel are then calculated using a fuel-based emission conversion factor. This may be done on the basis of including emissions that result from fuel production (a well-to-wheel) factor and can be formulated to include the impact of only $CO_2$ or to include other greenhouse gases (the $CO_2$ equivalent).

## *3.2 Industry Requirements*

The GLEC members have agreed that the framework must be based on the needs of industry (shippers, logistics service providers, freight forwarders and carriers) regarding where $CO_2$ (and other) emissions from freight transport need to be considered. This places practicality and comparability ahead of absolute accuracy which has often been shown to require an unrealistic amount of data.

This approach acknowledges the extent of data visibility to each of the organization types in the supply chain and the way in which it is passed between them in order to meet their decision making needs as the overall goal is to support an improvement in decision making and the effectiveness of reporting within the global logistics sector by shippers, LSPs and carriers, recognizing their differing needs.

The figure below illustrates the dynamics between shippers/customers (who want goods moved) and carriers (who transport goods) towards improving fuel efficiency and reduce emissions intensity. To achieve more efficient freight transport sector both are needed: shippers/customers must create a "pull" and carriers must create a "push" for change (Fig. 7).

Industry needs and gaps for each of these steps are illustrated in the Figure; for example shippers require harmonized methodologies for calculating and reporting emissions to be able to compare modes or carriers before making a freight purchase decision that considers fuel and the carbon footprint; carriers must have confidence in the performance of technologies before deciding to invest in them, and technology verification can contribute to that.

By addressing these needs/barriers we help the freight sector to accelerate the adoption of emission reduction measures as individual companies but more importantly, as collaboration efforts between carriers and shippers/customers.

It was previously noted that EN 16258 includes four incomparable levels of accuracy. In the language of EN16258 the GLEC members have decided that the level of "transport operator specific values" in is the best way to proceed. This is based on the fact that the operational data required to meet these needs must be sourced from the transport operator (carrier) as they are the organizations who have access to the real fuel used and work done information.

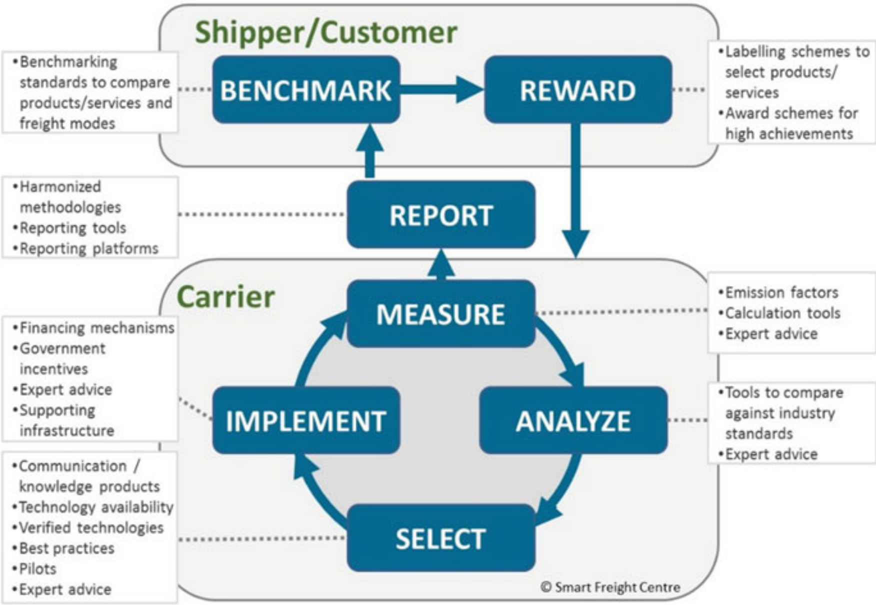


**Fig. 7** Shipper/Carrier interactions (Smart Freight Global Framework for Action 2015)

The GLEC framework already addresses some of the issues identified in previous research; for example, the relationship between different actors in the complete supply chain. It does this via use of the consumption factor as a common building block for all stakeholders. The calculation approach depends not only on the need but also on the organization's position in the chain—specifically if it is a transport service buyer or transport service provider. As can be seen from the diagram, LSPs (and freight forwarders) may have either role, depending on the nature of the transport service in question. Also, a combination is possible, for example a shipper or LSP could make use of a combination of its own fleet (which makes them their own "carrier") and subcontracted fleet (in which case they are the buyer) (Fig. 8).

The main distinction between the two roles is that the transport service buyer does not have access to data on fuel consumption, exact routings, filling rate, empty trips etc., nor is the transport service provider likely to share this because that would disclose sensitive cost structure information of the carrier. For this reason the transport service buyer will need to make use of consumption factors for the transport service clusters purchased. The carrier on the other hand should have fuel consumption data available, or at least average fuel use data for its fleet, and it makes more sense to use this data when the need is to calculate the company or product carbon footprint.

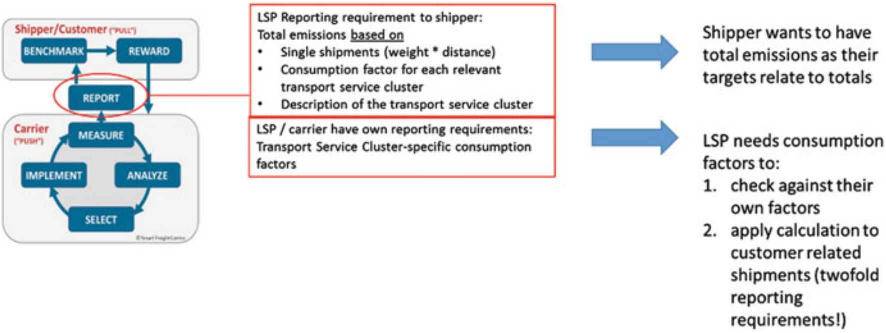


**Fig. 8** Shipper/Carrier reporting requirements (Smart Freight Global Framework for Action 2015)

## 4 Results and Application

The trips that are included within the calculation of the consumption factor must clearly be representative of the service that is being provided. EN 16258 acknowledges this by referencing a vehicle operating system (VOS), but then leaves the definition open, except that empty trips are always to be included.

The GLEC framework attempts to take this further with the concept of transport service clusters. Transport service clusters are groups of round trip journeys averaged over 12 months that represent the way that freight transport services are procured. This approach has been taken because it is in line with the needs of stakeholders of the freight transport, the more general description of vehicle operating systems in EN16258, taking an element by element approach to a more complex transport chain and the principles of practicality and reliability of results.

For consistency of comparison, the transport service clusters should be defined in a manner that is as homogenous as possible. The preference is to use transport clusters that are directly relevant to the mutual needs of the providers and users of the transport service. This will likely result in data with medium granularity that is sensitive enough to make system changes visible within the consumption factors, but not over-sensitive to volatilities that are outside the influence sphere of industry or require unreasonable amount of data to fulfil them (attempting to respect the principle of simplicity and practicality).

The detailed basis upon which transport service clusters should be defined will vary depending on the nature and structure of the transport service provided and the mode used. The definitions of the basis of potential transport service clusters for the various is still being defined by the GLEC industry partners.

Work is still required and ongoing on several issues (Davydenko et al. 2014).

As existing methodologies are not based on consistent conversion factors from fuel to emissions then this needs to be addressed so that there is a clear approach by mode, fuel and global region for well-to-wheel $CO_2e$ emissions.

Default factors for different modes/transport service clusters are needed for use in circumstances where carriers are, for whatever reason, unable to provide their own operational figures.

Targeted research on issues such as evaporative/fugitive emissions, energy use of different types of temperature controlled containers, the impact of black carbon emissions needs to be conducted.

Finally, practical validation of the approach, particularly in respect of data availability at source, the ability to share among all stakeholders in the supply chain and the ability to support environmental decision making has to be carefully planned and undertaken.

Further harmonization and a broader scope is expected by 2017 as a result of this work, and is partly dependent on additional funding for some of the activities contained within the GLEC roadmap.

## References

Arrêté du 10 avril 2012 pris pour l'application de l'article 14 du décret n° 2011-1336 du 24 octobre 2011 relatif à l'information sur la quantité de dioxyde de carbone émise à l'occasion d'une prestation de transport. http://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000025706344

Auvinen H, Makela K, Lischke A, Burmeister A, de Ree D, Ton J (2011) COFRET Deliverable 2.1. Methods and tools for calculation of carbon footprint of transport and logistics

Auvinen H, Clausen U, Davydenko, I, de Ree D, Diekmann D, Ehrler V, Lewis A, Ton J (2013) Calculating emissions along supply chains—towards the development of a harmonized methodology. In: 13th WCTR, Rio de Janeiro, Brazil

Blanco E (2014) Assessing global freight emission methodologies. GLEC Strategy Annex, Smart Freight Centre

COFRET Final Results Report (2014) http://www.cofret-project.eu/downloads/pdf/COFRET%20results%20report_final.pdf

Davydenko I, Ehrler V, de Ree D, Lewis A, Tavasszy L (2014) Towards a global $CO_2$ calculation standard for supply chains: suggestions for methodological improvements. 93rd Annual meeting Transportation Research Board (TRB), 12–16 Jan 2014, Washington, United States of America

International Transport Forum (2013) ITF Transport outlook 2013: funding transport. http://www.keepeek.com/Digital-Asset-Management/oecd/transport/itf-transport-outlook-2013_9789282103937-en#page1

ISO (2015) International harmonized method(s) for a coherent quantification of $CO_2$e emissions of freight transport. ISO IWA #16. http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=67844

Smart Freight Global Framework for Action (2015) http://www.smartfreightcentre.org/main/info/downloads

World Economic Forum/Accenture (2009) Supply chain decarbonisation. World Economic Forum, Geneva

# Index





M. Lu, J. De Bock (eds.), *Sustainable Logistics and Supply Chains*, Contributions to Management Science, DOI 10.1007/978-3-319-17419-8