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MARITIME PORTS, SUPPLY CHAINS AND LOGISTICS CORRIDORS

Edited by

Cyrille Bertelle, Nathan Gouin and Antoine Frémont

ROUTLEDGE

Maritime Ports, Supply Chains and Logistics Corridors

This book aims to highlight the interrelations between maritime ports, supply chains and logistics corridors. Inland corridors could be defined as major arteries for inland transportation from and to the maritime port. They link together one or several ports located on the maritime range with one or several major inland metropolitan areas. The efficiency of international supply chains depends not only on the smooth operations in the port but also on the efficiency of inland distribution in terms of cost, reliability, added value services for the goods, safety and finally the environment.

With contributions from international experts, the book offers a transversal perspective on logistics corridor development using case studies on the Seine Axis, among others. Organized into four key sections, the book highlights the interrelations between ports and corridors using both empirical and theoretical research from various disciplines, including engineering as well as human and social sciences.

Maritime Ports, Supply Chains and Logistics Corridors will be directly relevant to a wide variety of scholars and postgraduate researchers in the fields of transport studies and management, maritime logistics, supply chain management and international logistics as well as industrial engineering, geography, economics and political science.

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Contents

Preface

As its name suggests, the purpose of the Délégué interministériel au développement de la vallée de la Seine (DIDVS) (Interministerial Delegation for the Development of the Seine Valley) is to promote initiatives, projects, and measures designed to ensure the balanced, relevant, and sustainable development of this territory.

The status granted to this corridor by the French prime minister, positioning it as a major avenue for development, is indicative of the importance of the Seine Valley for the French government in terms of its demographic, geographic, economic, environmental, and social characteristics.

Within the framework of a unique tool in France – namely, the Contrat de plan interregional état-régions (CPIER) Normandie et Île-de-France (Normandy and Île-de-France state-regions interregional plan contract) – the interventions undertaken by the delegation are intended to promote the regulation of flows and movements, with a particular focus on logistics issues, and to strengthen ties between the realms of economics, academia, and research.

This is where the present work, "Maritime Ports, Supply Chains, and Logistics Corridors," comes in. It offers an illuminating insight into the challenges associated with transport and logistics issues, as well as reinforcing the desire to take action and build on the ideas explored in this research study.

Without going into each chapter in too much detail, I wish to make the following three remarks on their content, as well as their overall structure, to highlight the depth and scope of this academic work:

- First, the introductions to key economic, technical, and geographic elements, and to the challenges and strategic dimension of ports and corridors, highlight the major trends of a context characterized by crises and the emergence of new parameters: the aftermath of the health crisis, the war in Ukraine, the assertion of the global role of China, the quest for sovereignty, the impact of traffic in the future Seine–Nord Europe Canal, and so on.
- Second, the exploration of less traditional themes is also welcomed in this work, thereby offering a broader overview of topical issues in the maritime sector, such as the contribution of modern technologies on the one hand, and the impact of the environmental and energy transition (energy, hydrogen, local distribution, etc.) on the other.

- Third, the legitimacy of the research conducted is also apparent throughout this book, whether it pertains to the Seine Axis, the focal point of most chapters, or it extends to other territories, allowing relevant geographical comparisons to be drawn.

In fact, while the Seine Valley is one of France's main ports of entry for international flows of goods, the focus has long been on the nature, quality, and reliability of infrastructure. The theme of governance and scale has since come to the fore. Indeed, In June 2021, a major river–sea port complex, "Haropa port," was created thanks to the merger of the three autonomous port authorities of Le Havre, Rouen, and Paris. Haropa port's 2020–2025 strategic plan, which is set to receive investments of €1.3 billion, is designed to enable the port to achieve traffic objectives of 92–95 million tonnes of goods.

Nowadays, in the context of a globalized world, offering and delivering high-performance services are considered paramount at every step in the supply chain. Gaining a competitive edge and capturing market shares also hinge on the "customer service" aspect, that is the provision of operational solutions that facilitate the purchase or use of products and services.

Consequently, the "infrastructure-based" approach to transportation and logistics issues is gradually giving way to a more comprehensive "end-to-end" vision of the maritime sector.

This publication highlights that the multidisciplinary approach it introduces and develops – fostering close collaboration between academics and, in particular, facilitating the involvement of various port stakeholders – offers a great deal of promise. From the analysis of impacts of substantial investments to the improvement of contracting processes, and the streamlining of trade flows or the regulation of cooperation among stakeholders, it is crucial that research and production requirements are reconciled to the benefit of customers.

Separating research and development from commercial activity would be an impossible task. Indeed, they are intricately linked. Research is significantly more effective when it is conducted in coordination with production, and, given the context of new digital technologies and environmental challenges, the subject is more salient than ever.

The goal here is to embark on a strategic and proactive approach through a collective, considered, and organized effort, with a view to leveraging any possible competitive advantages in favour of the Seine Valley to foster growth in terms of market share and employment.

In addition, this ambition raises the collateral issue of human resources: going forward, the actors involved will also have to address matters of training (and possibly retraining) existing staff members, as well as the recruitment and retention of new talent.

This vision will also have to increasingly account for multiple factors: support for innovation, land supply and sobriety, and as already mentioned, environmental excellence, particularly with regard to decarbonization.

The DIDVS has set itself the task of meeting these requirements. One way it plans on doing so is by increasing the visibility of such efforts within the Seine

Valley community to further build on the contributions of partners and thus foster a more panoramic appreciation and understanding of the work carried out along this major corridor.

Where necessary, the DIDVS is also committed to deepening ties between local and national actors, such as within the framework of the work conducted by the Comité interministériel sur la logistique (CILOG) (Interministerial Committee for Logistics). This would stand to benefit the territory and its actors, logistics, related services, and environmental responses.

It is in this spirit that, on behalf of the DIDVS, I would like to express my full support for this publication. I would also like to thank the authors for the quality of their contributions and the project leaders for preparing this work. I hope that future readers find its content both enriching and enjoyable.

Prefect,
The Interministerial Delegation for the Development of the Seine Valley
Pascal Sanjuan

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Introduction

Antoine Frémont, Cyrille Bertelle and Nathan Gouin

Maritime ports, supply chains and logistics corridors

Why bring three seemingly distinct elements – maritime ports, supply chains and logistics corridors – together under the same title? Let us begin with an explanation of this connection, as it constitutes the central premise and guiding principle of this book. Today, logistics corridors are an essential driver for the analysis, optimization, and transformation of the activities of seaports and supply chains. The aim of this book is therefore to show how these corridors shape the rivalries between seaports and supply chains along a given maritime range or even along different maritime ranges. In addition, the objective of this work is to define the ways in which these logistics corridors may influence the major digital, energy and environmental transformations faced by ports and supply chains. Confronted with such a complex subject matter, a multidisciplinary approach was adopted. Given the number of French contributors to this book, the Seine Axis – the major axis that runs through Paris along the Seine River – forms a privileged field of study. Nevertheless, this work also features the examination of other logistics corridors, alongside more theoretical or comprehensive approaches to complement these case studies.

In terms of volume, maritime transport constitutes 90% of world trade, making it an essential vehicle for globalization. A wide range of different goods and activities are handled in seaports: from liquid or solid bulk, various containerized goods, to ro-ro traffic (where vehicles are "rolled on" and "rolled off" a vessel or trailer) as well as passenger traffic for ferries or cruise ships. Serving as key transshipment points for goods, ports play an interface role between land and sea and contribute towards the organization of international supply chains. Since the *Trente Glorieuses*, a 30-year period of economic growth and prosperity following the Second World War, port facilities in industrialized countries have also provided important industrial functions, most often in connection with maritime traffic. They occupy vast stretches of coastline, often in the immediate vicinity of large cities.

Though decades old, André Vigarié's notion of the "port triptych," which emphasized the central position of seaports in the development of land transport and sea transport flows, is still very much relevant today (Vigarie, 1979). Ports serve as key hubs where cargo is unloaded and distributed between different terminals. They also act as industrial sites for the transformation of goods. At the

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forefront of a marine foreland, ports consolidate all the maritime connections linking them to other ports. They exert control over the activities of their respective hinterlands, which correspond to the market area of a port. The port, its foreland, and its hinterland are interdependent and comprise several components: infrastructure, services as well as both public (e.g. port authorities) and private (terminal operators, shipowners, freight forwarders, etc.) actors who implement these services. The port triptych concept has manifested itself in various ways, a testament to the increasing integration of transport chains and the growing interdependence of its three constituent elements.

More recently, this port-centred approach has given way to an increased focus on the concept of the supply chain. Supply chains are defined as the complete process of transporting goods from the point of departure, the shipper, to the point of arrival, the end user. Managing supply chains involves not only the physical organization of flows according to the requirements of shippers or customers, but also the processing of informational and financial flows generated by the physical movement of goods. These supply chains are an integral part of production or distribution chains and play an important role in determining their competitiveness.

Within these supply networks, seaports are just one link in a vast distribution chain; they form part of a larger system that allows for a wide range of routing scenarios. The same supply chain may involve competition between ports on the same maritime range, or even on a continental scale, between different maritime ranges. To take up the title of Slack's 1993 paper, which still proves relevant today, ports are often merely "pawns in the game" (Slack, 1993) Indeed, the organization of these chains depends less on these seaports as port authorities and more on the various stakeholders responsible for the transportation of goods. These actors are connected through commercial relationships and include shippers, freight forwarders, shipowners, handlers and, more generally, logisticians.

The growing influence exerted by these logistics actors in the control of supply chains since the 1980s can be attributed to several factors. First, these actors have developed global networks in their core businesses: global maritime networks for container carriers, global terminal networks for terminal operators and global freight agency networks for freight forwarders. This horizontal integration has been a key factor in sustaining and driving the growth of international trade. Indeed, these logistics actors leverage economies of scale to handle considerable volumes and develop a network economy based on massification. This allows them to benefit from increasing returns and gradually establish dominant positions in the market, which in turn often results in oligopoly situations. This process is already well under way for liner shipping, as the concentration rates are so high.

The institutional transformation of ports since the 1980s was also a strong driver of the emergence of these actors as global players. The "tool port" model, akin to a state public service, has been replaced by the "landlord port" model, which has become widespread worldwide since the 1990s. In the latter model, port authorities take on the role of landlords, exercising their regulatory authority over their respective hinterlands. They are responsible for the development of the area surrounding the port and for investing in infrastructure, as well as for leasing, for varying durations, the operation of terminals to handling companies.

Port terminals have received significant investment from both shipowners and cargo handlers. In the initial stages of these investments, this support allowed regular shipping lines to secure their maritime networks, which rely on a small number of major loading/unloading ports along each maritime range. These loads centres primarily serve major important metropolitan markets and, therefore, their respective hinterlands. In these pivot ports, regular shipping lines own, often in joint venture with a cargo handler, a terminal that allows them to concentrate and massify their maritime calls. In addition to these pivot ports, there are also intermediary hubs along main maritime routes that facilitate the expansion of the number of maritime links as well as the consolidation of traffic. Certain pivot ports also serve as hubs. In the second phase of this investment process, container carriers and terminal operators have been able to develop land-based rail or river networks from their largest maritime terminals to inland terminals. These terminals are often located in major cities, at the heart of consumer or production markets. This approach serves to massify inland flows and thereby alleviate congestion at the busiest maritime terminals. Achieving economies of scale within these inland networks also makes it possible for port facilities to gain a competitive edge in their existing hinterland, while also expanding its reach beyond conventional boundaries.

Port authorities have a vested interest in consolidating and expanding their hinterlands, as it allows them to capture the market shares of other rival ports. Port authorities play an essential role in coordinating and planning major territorial developments over the long term. The development of land-based infrastructures, in particular mass transit networks such as motorways, railways and waterways, contributes to the massification of port activities. In addition, railways and waterways are now widely recognized for their role in decarbonizing transport and supporting the environmental transition. The planning of land reserves within and beyond the port perimeter, as well as in the hinterland (including the distant hinterland), is equally crucial. Effective planning allows for the establishment of intermodal, logistics or industrial activities that require a great deal of space, which is increasingly scarce in most densely populated areas. Supply chain activities must also compete with other urban functions that boast a higher added value. Furthermore, achieving "zero net artificialization" is necessary to preserve biodiversity, which poses an additional constraint for the development of supply chain activities. When it comes to carrying out long-term territorial planning work, the port authority is only one actor among other public institutions. Coordination among the state, local authorities and municipalities is necessary when determining transport infrastructure routes, allocating land for supply chain activities and securing the necessary funds for these investments. These infrastructure projects often extend beyond the framework of the port itself and take on a regional and often national dimension. The larger the port, the more important the role of the port authority will be in coordinating public actors, and vice versa.

This process is now widely recognized in the field of logistics: massification creates a snowball effect that is self-sustaining and that spans various segments of the transport chain (Figure 0.1). At sea, for instance, we see the use of increasingly large container ships, and these ports of call are justified by the significant volumes handled. Ports located in the heart of metropolitan markets benefit from this

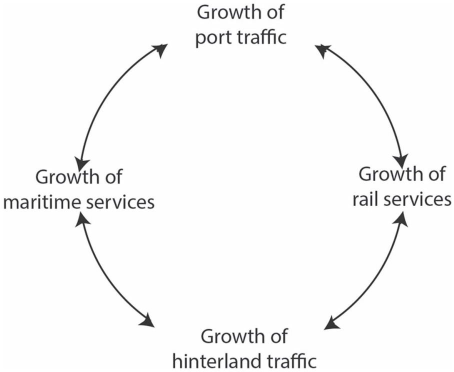

Figure 0.1 The snowball effect.

advantage. The use of massive inland transport is justified by large volumes, making it possible to expand the hinterland. This expansion requires the establishment of inland terminals and logistics areas, as well as land, to facilitate the collection and distribution of goods in inland metropolitan areas.

This snowball effect of massification progressively modifies the port hierarchy along the same seafront in successive stages (Figure 0.2). In their 2005 paper, Notteboom and Rodrigue proposed the term "port regionalization"[1] to describe this phenomenon. The port or the ports that benefit from the snowball effect expand their hinterland, gradually capturing the hinterland of so-called secondary ports. The latter cannot rely solely on what Hayuth called the "peripheral port challenge" (Hayuth, 1981) to hope to attract maritime and inland traffic, whereby secondary ports located far from major markets and trade routes struggle to compete with central rival ports. These port facilities must therefore overcome these spatial and logistics challenges if they are to establish themselves as viable alternatives and attract maritime and inland traffic. Indeed, large ports invest massively in terminals or inland services to limit the effects of congestion, ensuring that they can fully reap the benefits of the massification process. Secondary ports must therefore try to implement their own massification strategies to counter the risk of being dominated by larger ports. A good example of this can be found in the Seine Axis, where the ports of Le Havre, Rouen and Paris have joined forces to form a single entity in 2021, Haropa port.

Together with the emergence of this competitive landscape, the rise in health crises (the COVID-19 pandemic) and international tensions (the war in Ukraine, strategic rivalries between Western countries and China) has caused states, particularly those in the West, to reconsider the status of ports. Indeed, in order to avoid commercial and industrial dependence, ports are increasingly positioned as strategic locations closely linked to national sovereignty. In a movement away from such dependence, the origin of private investments is, for example, increasingly monitored (Frémont, 2021). In addition to being crucial interfaces for the routing

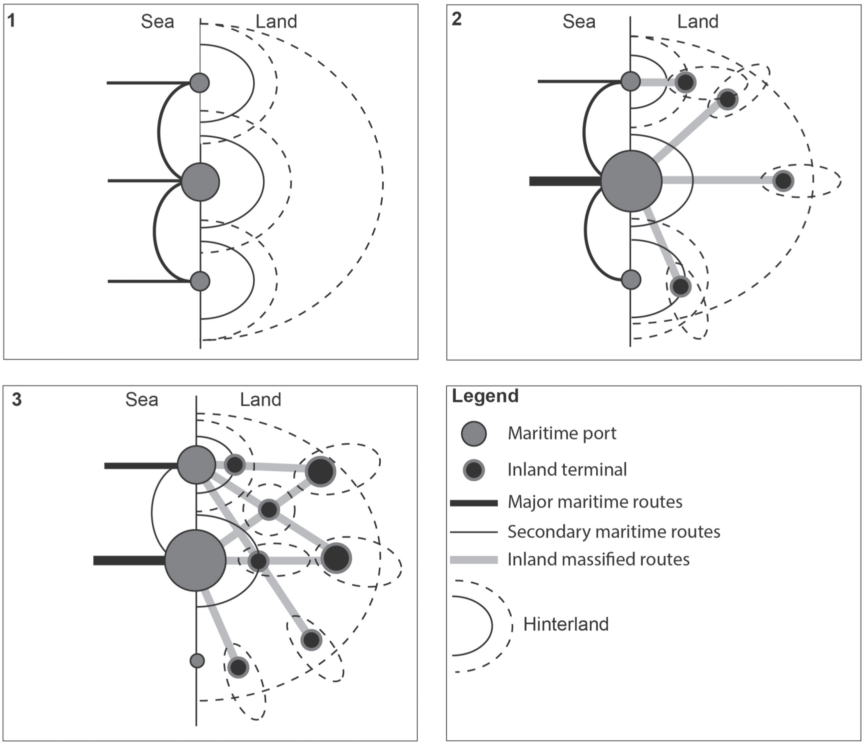

Figure 0.2 Inter-port competition for hinterlands: theoretical schemes.

of foreign trade flows, ports also house vast industrial areas where heavy industries inherited from the post-war are located. The strategic importance of oil and petrochemical, steel and shipbuilding complexes was made apparent in the face of international crises. Not only are these industrial complexes vital for supplying essentials such as fuel or steel, but they also underpin the success of operations within other industries. Moreover, these industrial areas offer opportunities for the implementation of energy transitions through the development of renewable energy sources such as wind power and, in the years to come perhaps, hydrogen. The laws of the market alone are not always applicable to port systems, and their distinct geopolitical dimensions can no longer be ignored.

For a comprehensive analysis of supply chains to be possible, encompassing the multiple forces at play – from competitive and environmental to social, political and geopolitical factors – their territorial dimension must also be taken into account. This is where the concept of “logistics corridors” comes in. Ports correspond to specific locations, but the other parts of the supply chain also have their own distinct locations. They are not abstract concepts but rather are embodied in specific settings, such as logistics zones, and they connect different locations through transport and information flows. These locations may be subject to physical, topographical, climatic or biogeographical constraints, which can impact the organization of flows. Similarly, the "actors" involved in supply chains include companies, institutions and individuals employed by these entities, who work in a variety of different places. In ports, they form port communities because of their close geographical proximity. However, they also maintain connections with their colleagues in the same company, with their customers and with their competitors on other scales related to the networking of supply chains, such as regional, national, continental and global scales.

The massification of supply chains, both maritime and inland, naturally leads to the concentration of traffic along a few specific routes, which come to form corridors. These corridors necessarily have a seaport as their outlet, with an axis making it possible to link major inland cities to this maritime gateway. These corridors are characterized primarily by the concentration of multiple transport infrastructures, motorways, railways, waterways and pipelines on a relatively small stretch of road. This stretch often corresponds to a valley located between the maritime outlet and connected inland cities. Due to the concentration of transport infrastructures, corridors benefit from a great deal of visibility, especially since these infrastructures – save a few rare exceptions – are not solely dedicated to supply chains but also accommodate other passenger or local goods traffic. The infrastructure of corridors is also embodied by their related industrial or logistics activity zones. These zones are located within ports and all along corridors, often on the outskirts of large cities where nearby production and consumption markets are situated. Additionally, the structure of a corridor is materialized in the cities that form its axis, expressed by the tertiary activities necessary for the design, organization and operation of its associated supply chains: head offices or back offices of the many companies involved, as well as the headquarters of the public institutions responsible for defining public policies and regulating various activities.

These corridors can vary significantly in size. They may just span a few dozen kilometres between a port and an inland logistics centre, or extend for hundreds of kilometres and take on a continental scope, as in the case of the Rhine corridor. These corridors can also include land bridges that connect two maritime ranges.

The notion of a corridor reinforces the territorial dimension of supply chains and therefore logically places emphasis on the land-based organization of supply activities. As a result, it challenges the unequal size of each port's hinterland. At the same time, the corridor concept acknowledges the role of maritime transport in the supply chain by integrating its dependence on these transport modes into the functioning of the corridor.

The hypothesis presented in this book is that corridors play a pivotal role in inter-port competition. These corridors pave the way for the implementation of global strategies by logistics chain operators. Global alliances, as well as more local ones, are formed within these corridors, since global operators must rely heavily on territorial economic forces. These alliances reveal opportunities for coopetition between companies, based on vertical or horizontal integration. In addition to the competitive forces at play, economic players, whether global or local, come up against the various social, political and cultural realities of the territories they are involved in. Public policies guide their choices of logistics locations and decisions on the use of corridors, going beyond a mere analysis of the market, its size and level of competition.

The organization of supply chains has been heavily impacted by the major transformations shaking up the modern world. For instance the climate emergency, and more broadly, the environmental emergency, including the challenges surrounding the preservation of biodiversity, are reflected in the objectives drawn up by logistics operators, who increasingly strive towards decarbonization and the drastic reduction of all forms of pollution for both maritime transport and ports. The energy transition aims to move away from a world of transportation that is heavily reliant on fossil fuels to a new, ecological model that promotes the use of decarbonized and less polluting energy sources. Furthermore, supply chain organization has also been shaped by the development of digital technologies, which has led to the growth of robotics, increasingly used in the physical operations of the transport chain, particularly in warehouse settings. In addition, recent transformations are also reshaping information systems, facilitating better coordination between transport chains stakeholders and improving the monitoring of physical and financial flows.

In the context of inter-port competition, corridors are optimal locations for stakeholders to respond to the major contemporary transformations impacting supply chains. Indeed, in these corridors, the interests of the various supply chain actors may converge or diverge, and they may or may not share common objectives when it comes to tackling these major transformations. While these changes present growing constraints in today's world, they also provide opportunities for differentiation and comparative advantages in the world of tomorrow. Each player involved in the supply chain can seize these opportunities individually or embark on collective ventures at the corridor level.

A multidisciplinary approach

The purpose of this book is therefore to present analyses, studies and models relating to the impacts of current transformations on logistics corridors and their functionalities. Given the diversity of these transformations and the great complexity involved in the organization of corridors, along with the numerous actors involved in operating them, a multidisciplinary approach is required. First, geography provides an understanding of the spatial configuration of maritime gateways and corridors, as well as their impacts on the development of port infrastructures. Second, a management-based analysis is necessary to examine the functionalities of these infrastructures and their alignment with the supply chains operating within corridors. These supply chains generate (1) flows of goods that require transport-related considerations and skills, (2) financial flows that require economic expertise and (3) information flows that rely on specific information systems and require IT expertise. The search for efficiency in these flows also leads to the mobilization of mathematical modellers, particularly in operational research, in order to optimize overall processes and to fully account for their contextual complexity. A combination of this interdisciplinary expertise is crucial to effectively analyse and provide solutions that can help resolve the problems encountered while also preserving the complexity of these systems. Integrated approaches are then necessary to preserve their intelligibility.

Furthermore, beyond the academic skills mentioned earlier, it is essential that the expertise employed aligns with the needs of a territory, which functions as a complex system bringing together a multitude of operational actors. Indeed, continuous dialogue between operational actors and academic experts is crucial in formalizing co-constructed problems capable of managing and developing the territories impacted by the major transformations shaping the world today. Through the appropriation and integration of various disciplines, collective solutions can emerge, which in turn contribute to the development of territories and corridors, as illustrated in Figure 0.3.

The analysis and measurement of the impacts of current transformations, as well as the need to adapt logistics processes within corridors, provide immense scope for future innovation. These approaches therefore require the community of economic players and academic researchers to organize themselves effectively

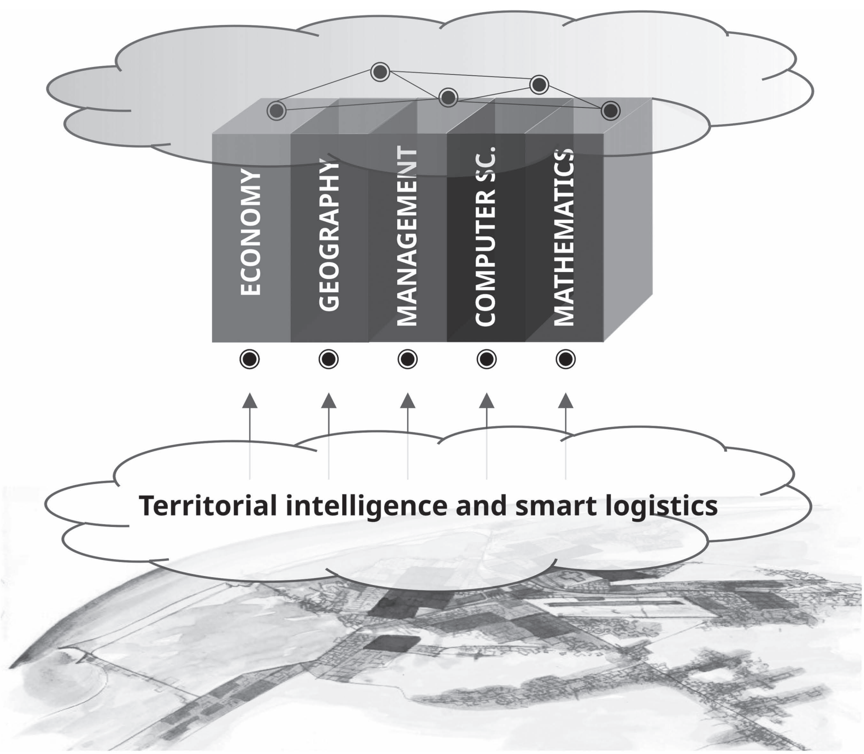

Figure 0.3 Bringing together interdisciplinary skills to address corridor issues.

at a local level so that the associated corridor can address the major economic challenges of globalization, as well as the environmental and societal issues that arise from it. While the major ports of Northern Europe have been successfully involving academic experts and academics in their development policies for several years, such an approach presents more institutional and cultural challenges in the major port centres of France.

The Seine Valley, the driving force behind these collaborative efforts in France, set itself the task in 2017 of bringing academic forces together to form a consortium aimed at opening up dialogue with economic and public actors. The objective of this endeavour is to mobilize cutting-edge expertise capable of identifying the challenges involved with transforming logistics processes, while also factoring in territorial challenges and the involvement of local actors. With this aim in mind, the Smart Logistics Institute in Seine Valley was born, initially under the status of a scientific interest group (SIG). This institute has since become a gateway for the involvement and consultation of academic forces dedicated to corridor logistics, which aim to promote territorial intelligence on the Seine Axis. This approach has already yielded results by port actors, such as the ambitious joint venture of various port facilities to form the Haropa port complex.

While the Seine Valley corridor is naturally a key objects of study for the Smart Logistics Institute, collaborative research approaches are also encouraged, with the aim of generating innovative development ideas that can be adapted to other corridors on a national scale. This approach also allows for comparisons to be drawn with similar undertakings carried out on an international scale.

This book therefore seeks to build on the exchanges and discussions that have taken place within this institute and to invite national and international communities the world over to further explore the issues, challenges and sources of innovation related to ports, supply chains and logistics corridors.

Book contents

Without claiming to provide an exhaustive investigation on the topic, this book aims to explore the many dimensions involved in logistics corridors. To do so, an original multidisciplinary approach was adopted, bringing together contributors from fields including operational research or computer sciences as well as researchers in the human and social sciences (management, geography and law). It should be noted that all the chapters have been subject to a rigorous scientific evaluation.

To reflect the diversity of issues and dynamics at play within logistics corridors, from maritime ports to last-mile delivery in metropolitan areas, we have divided this book into four sections:

- corridor-level thinking: competition for the hinterland
- the geopolitical challenges surrounding corridors
- the digital shift to optimize logistics corridors
- the promotion of sustainable corridors through environmental and energy transitions

The first section explores different issues raised by the organization of the supply chain at the corridor level through the lens of inter-port competition. In Chapter 1, Antoine Frémont analyses the way in which seaports and airports take on the role of gateways within metropolitan areas, as well as their impact on the structuring of the centripetal and centrifugal forces that characterize these areas. After conducting a cross-analysis of the different types of urban networks, Frémont proposes a typology of metropolitan gateways, consisting of the maritime metropolis, the maritime- or land-dominant metropolized inland corridor, the metropolized maritime conurbation and the metropolized maritime range.

In light of the major trends that have characterized maritime supply chains over the last decade, in Chapter 2, Francesco Parola looks at the role that regulations can play in improving the functioning of individual sub-markets, particularly in order to address the risks of infrastructural under-capacity in ports following the increase in ship sizes and the challenges of connecting to the hinterland, as well as to tackle the growing concentration of logistics actors. Parola highlights the importance of economic regulation in ensuring efficient and transparent market dynamics by drawing on examples from the Italian sea-land transport industry.

Through the example of the Seine Valley, which links the maritime port of Le Havre to the global city of Paris via the Seine River, the first section of this book also explores various issues relating to the organization of the supply chain in a predominantly land-based and metropolized inland corridor. Ronan Kerbiriou (Chapter 3) uses a geographic information system to demonstrate that, despite the advantages offered by the Seine River's natural infrastructure, the hinterland of the Haropa port complex (a joint venture between the ports of Paris, Rouen, and Le Havre) is strongly challenged by flows originating from Benelux ports (notably Antwerp) via road transport. This is primarily due to the location of the logistics warehouses in the Paris metropolis on the opposite side of the river, which results in river-road intermodal transport being more costly than using road transport alone.

This analysis is continued in Chapter 4, where Patrick Niérat and Sacha Rybaltchenko present a calculation method to compare the costs of intermodal transport with road transport. By presenting a range of different scenarios, the authors shed light on the importance of the first and last kilometres in intermodal transport and the comparative advantages of transport solutions depending on the final destination in the Île-de-France region.

In Chapter 5, Laurent Guihéry discusses a public investment project aimed at enhancing the competitiveness of the port of Le Havre in the face of other rival ports in the Northern Range, as well as promoting the massification of transport: the construction of a Serqueux–Gisors rail section, a project to develop a rail freight corridor between Le Havre and Paris. This solution, set to pave the way for greener modes of transport, is currently coming up against challenges related to cost competitiveness and land-use conflicts in the densely populated Île-de-France region, including trade-offs between freight and passenger passport, as well as NIMBY [not in my back yard] behaviour.

Finally, in Chapter 6, David Guerrero, Adolf K.Y. Ng and Hidekazu Itoh conclude this first section with an examination of the role of maritime ports and logistics corridors in a rapidly changing industrial sector: the automotive industry. To do so, the authors focus on the role of parts consolidation centres (PCC), distribution facilities where parts are sorted and packed into containers. In this chapter, the authors point out that while ports in advanced economies have an opportunity to stake their claim in this promising sector, local PCC activity generates little added value and is subject to demand instability.

The second section includes four chapters on the role of logistics corridors in political and strategic projects at various scales. To this end, Laurent Livolsi and Christelle Camman (Chapter 7) demonstrate that in a shifting global supply chain, the strategies of large companies and states converge in seaport areas and, more broadly, logistics corridors. The authors highlight the strategic role of logistics corridors in securing national sovereignty, specifically in the context of China's Belt and Road (BRI) Initiative and the tensions this ambitious venture generates.

Then, Antoine Beyer (Chapter 8) situates the Seine Axis in the context of the European TEN-T network policy, raising questions about the coherence between national and European planning schemes. Indeed, despite being part of the TEN-T network, an ongoing interregional project, set in motion back in 2008, aims to position the Seine Axis as the maritime gateway to the Île-de-France metropolis, which serves as its terminus. This issue of the passage from Paris to the East, which would allow for full integration into the European network, remains unresolved.

Rather than exploring the numerous political initiatives mobilizing the notion of corridors, in Chapter 9, Nathan Gouin and Arnaud Brennetot instead focus on their governance. They emphasize the significance of addressing planning, economic and environmental concerns and also identify, from a neo-institutionalist perspective, the causes of governance failures through the example of the Seine Valley, where the absence of long-term political leadership is a key factor.

Chapter 10, written by François H. Guiziou, focuses on the issue of corridors in the context of Ethiopia, a landlocked state gripped with social and political tensions. While a large part of Ethiopia's economic activity is concentrated in the capital Addis Ababa – which is heavily reliant on the port of Djibouti, with which it is strongly linked – Ethiopia is implementing measures to reduce this dependence by developing alternative routes to ports in Sudan and Kenya. However, the region's insecurity, coupled with the Ethiopian government's indebtedness due to ongoing conflicts, poses significant obstacles to this proposed strategy, particularly since the development of these alternative corridors requires substantial investments.

The third section is dedicated to the optimization of corridor supply chains through the use of new technologies and scientific research in operations development. In Chapter 11, Gülgün Alpan, Hamza Bouzekri and Éric Sanlaville highlight the importance of optimizing port operations to enhance supply chain performance and the sustainability of port facilities. During these optimization processes, various factors and stakeholders come into play when making decisions from the port to the hinterland, which can result in conflicting interests. The authors then demonstrate how operations research can be employed to model and resolve such decision-making dilemmas using a case study in Morocco.

In Chapter 12, Claude Duvallet, Cyrille Bertelle and Mongetro Goint first show how blockchain technology can prove valuable in the digitalization of logistics transactions, since it establishes high levels of security and trust. However, the authors also highlight the ongoing doubts expressed about this technology regarding its complexity, energy consumption and the uncontrolled speculation of values.

In Chapter 13, Brian Slack, Claude Comtois and Philippe de Champlain, through an analysis of the St. Lawrence River corridor, show how new technologies can be used to facilitate river transport in areas where navigation proves more complex by providing information on weather conditions or water levels in real time. More broadly, this chapter explores the theme of the "smart corridor," which involves harnessing technology to enhance levels of safety, security and logistics fluidity.

The next two chapters highlight the contribution of operations research in the form of simulation models. In Chapter 14, Julius Bañgate, Dominique Fournier, Éric Sanlaville and Thibaut Démare discuss the advantages of multi-agent models to design and simulate the behaviour of actors based on real geographical data. This model is used in two cases: first, to gain an understanding of the impact of the construction of the Seine–Nord Europe Canal on the flows in the Seine Valley and, second, to analyse how short sea shipping could reduce CO_2 emissions for a given industrial sector.

In Chapter 15, Aïcha Ferjani, Yasmina Essaghir, Amina El Yaagoubi, Jaouad Boukachour, Claude Duvallet and Mohamed Nezar Abourraja use another type of modelling to optimize multimodal transport within the Seine Valley corridor. The authors use two tools to demonstrate the methodological advantages of their approach: the first focuses on optimizing rail/road transport to reduce freight costs, while the second concentrates on the importance of synchromodality during a modal shift towards river transport.

Finally, *the fourth and final section* focuses on the impact of environmental and energy transitions within corridors. In Chapter 16, Marie-Laure Baron examines the opportunities created by the presence of corridor-level port authorities, such as the Haropa port complex. Port authorities' presence at the level of the corridor enables them, through economies of scale, size and corridor effects, to undertake a strategic approach to industrial and transport development allowing for the creation of "green corridors."

Next, in Chapter 17, Clément Lavigne and Sébastien Dupray offer insights into the effects of climate change and the ongoing upheavals in the energy sector on maritime ports and corridors. The authors evaluate the actions taken, at different scales and by various actors, to anticipate and assess future changes and possibilities.

In Chapter 18, Valérie Bailly-Hascoët delves into the legal aspects of the production and use of hydrogen as an energy source for transportation and logistics. Bailly-Hascoët draws a comparison between French and European strategies for the implementation of this energy source, its application regulations as well as its emerging uses.

Then, in Chapter 19, Roland Condor and Claude Duvallet look at the corridor as a potential means of enhancing short food supply chains. Despite often being perceived as a rival model to the global supply chain, which corridors are an integral part of, the authors show that short food distribution networks can in fact draw inspiration from the functioning of global food chains to meet the challenges posed by mass production and that achieving massification will be essential if these chains wish to respond to political demands.

Finally, in Chapter 20, Jakob Puchinger concludes this book by exploring an aspect of the corridor which, though not strictly related to seaports, does prove very much relevant for the analysis of supply chains: urban logistics or last-mile deliveries. More specifically, this chapter examines automated deliveries in cities, with a particular focus on the economic and environmental benefits they provide. The author also sheds light on the societal concerns raised by these technological developments. Puchinger emphasizes that for such issues to be resolved, collaborative efforts between private and public actors, as well as researchers, must be fostered to construct a shared vision for the future.

Note

1 See Notteboom, T. E., & Rodrigue, J. P. (2005). Port regionalization: Towards a new phase in port development. *Maritime Policy & Management*, *32*(3), 297–313.

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First section

Thinking at the corridor level

Competition for the hinterland

1 Geography of metropolitan gateways

Maritime metropolises, inland maritime corridors, and maritime regions and ranges

Antoine Frémont

Introduction

Metropolitan gateways exist at the interface between metropolization, international trade flows, and international transport (Bird, 1983; Alix, 2012). They are established through seaports and airports that, within the metropolitan area, create vast industrial, logistics, and/or services complexes in which tens of thousands of people often work. On a global scale, metropolises are connected through them, creating flows of goods. They allow goods to be distributed and collected in a potentially vast hinterland, in the metropolis itself, in the cities that are dependent on that metropolis, and also, via inland transport corridors, across the entire continent.

Our hypothesis has two components. Its starting point is the idea that in the context of organizing flows of goods, gateways articulate the concentration and dispersal forces that allow such flows to be bundled and unbundled. This articulation of two opposing forces is what defines a gateway. The second part of our hypothesis is that gateways are not uniform in terms of their geographical configuration, with the articulation of concentration and dispersal forces varying according to that configuration.

The chapter begins by putting forward a definition of a gateway that connects different spheres – international trade, international transport, and metropolization – and allows the flow of goods to be organized by articulating concentration and dispersal forces. Four different types of basic geographical configuration of gateways are then set out: the maritime metropolis, the metropolized inland corridor, the maritime conurbation, and the maritime range.

The metropolitan gateway: coping with different operating scales

On a small scale: the weight of concentration forces

Metropolises are masses. They are centres both of production and, owing to their population size, of consumption. On a global scale, metropolises and the regions that they polarize concentrate value chains through the advantages they offer: mass

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and centrality effects, ease of interaction, and economies of scale (Benko & Lipiez, 2000; Veltz, 1996). The growth of the international goods trade attests to globalization, which is taking place through metropolization (Sassen, 2000).

International transport hinges on this polarization brought about by metropolises. Transport serves trade. On a small scale, international maritime and air transport companies give prioritized service to metropolises, which in terms of goods and travellers are the most important production and consumption markets. Metropolises are prime markets, and such is their wealth that, compared to more secondary markets, they are worthy of being served directly and on a priority basis by international carriers.

International transport helps to strengthen this polarization at the largest metropolises by expanding the destinations served from them. Metropolises offer the advantage of being first-order nodes in inland transport networks. Motorway – and sometimes also rail and river – networks therefore make it possible to bring about massification of inland transport towards destinations that are also major market areas. This increase in the number of destinations from the same entry or exit point allows carriers to implement mass forms of long-distance transport. These produce economies of scale that are crucial in economic sectors with increasing returns in which it is difficult for a firm to distinguish itself from its competitors based on the quality of the service offered alone. After all, what could be more similar than two container ships or two cargo planes? It is therefore vital for carriers to fill their vehicles, whether these are ships or planes, at the biggest and richest hinterlands possible (Sdoukopoulos & Boile, 2020).

Inland corridors and hubs serving metropolitan concentration

Metropolises therefore control one or several inland transport corridors. An inland transport corridor can be defined as the juxtaposition, along the same relatively narrow axis, of several massified transport infrastructures (motorways, railways, canals) connecting several market areas. The latter comprise one or several very large cities that form an urban region. This corridor will have only a regional dimension if it connects cities in the same region. It will take on an interregional dimension if it connects cities from different regions. And it will assume a continental dimension if it extends across a continent to truly create a land bridge (cf. Table 1.1). These corridors play an essential role in the organization of logistics chains.

International carriers may decide to use ports or airports located in these metropolises as hubs in their networks. These hubs make it possible to bundle flows at one point and then better split them across different short-, medium-, or long-range destinations by reusing maritime or air assets. They occupy an intermediacy position within networks (Fleming & Hayuth, 1994). Many metropolises have both central and intermediacy characteristics. International carriers serve maritime ranges or secondary airports from their hubs. For example FedEx has made the Roissy platform its European hub. This airport allows it to serve not only Île-de-France and the entire French market over land, but also the rest of Europe by medium-distance air routes that take over from intercontinental ones. In the maritime context, the ports

Table 1.1 Examples of inland corridors.

Name	*Connected urban regions*	*Land-dominant transport infrastructure*	*Length*	*Dimension*
Seine Axis	Paris Rouen Le Havre	Motorways Railways River	250 km	Regional axis
Rhine Axis	Randstad The Ruhr Rhine-Main-Neckar Baden-Württemberg and Bavaria Basel	Motorways Railways River	1,000 km	Interregional axis
Yangtze Axis	Shanghai-Ningbo Nanjing Wuhan Chongqing Chengdu	River	> 2,000 km	Interregional or continental axis
North American Land Bridge	Between cities on the North American West Coast and Chicago	Railway bridge	> 3,000 km	Continental axis

of Rotterdam and Busan (South Korea) are not only hinterland ports but also hubs – the former for North Europe, the latter for North Asia. Ports and airports located in the world's largest cities therefore very often play a hybrid role: they provide both a load-centre function for flows going from or to the hinterland and a hub function. In this respect, they differ from pure hubs, which owe their activity exclusively to their position as intermediacy locations within networks and sometimes have no connection to any metropolis. These pure hubs – Algeciras and Gioia Tauro in the Mediterranean for example – are "out of touch" with the region in which they are located. Contributing little or no added value to their region, they are not involved in metropolization (Slack & Gouvernal, 2016).

On a small scale, metropolises are all massification points for international flows. Their accessibility allows international carriers to concentrate their services on them in order to bring about massification of flows, an essential source of economies of scale. And it strengthens metropolitan concentration via a snowball effect (Figure 1.1).

On a metropolitan scale, fragmentation and dispersal

This polarization of international flows on a global scale corresponds to the possibility of splitting flows up and distributing/collecting them on a metropolitan scale. This capacity is premised on a very high level of accessibility, which is itself based on the density of communication – and primarily motorway – networks. The phenomenon of saturation notwithstanding, these networks allow quick access to any

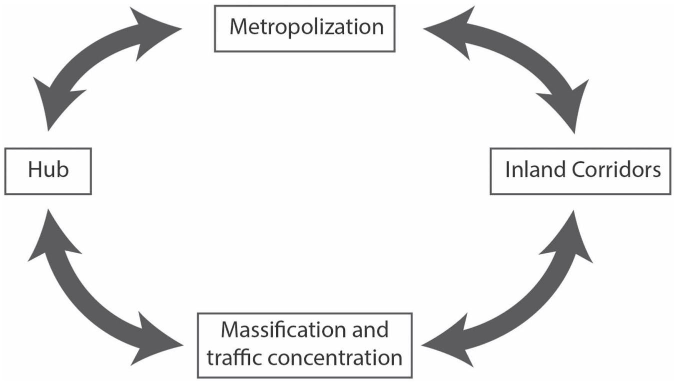

Figure 1.1 Metropolization and concentration of traffic: the snowball effect.

point in the metropolis. They are essential to the logic of door-to-door transport. Seaports and airports are sites of massification and polarization on a global scale, and as gateways, they are also sites where goods are split up (in the case of imports) and consolidated (in the case of exports) on the metropolis' local scale.

Based on road transport and a vast network of warehouses, the highway system, by dealing with last-mile logistics, makes it possible to satisfy, on a priority basis, this very wide dispersal of international flows at the local scale of the metropolis. Multiple factors explain this dispersal of flows over time and within the metropolitan space. There are many goods to be distributed. This trend is continuing to gain momentum as goods become more varied, shipments become lighter, and just-in-time delivery becomes more common. E-commerce best demonstrates this (Dablanc, 2019). Each economic sector, or even each company, has its own logistics organization. Land prices, which decrease the further the land is located from the centre, encourage activities to sprawl and become dispersed.

The logistics system itself is a major contributor to this sprawl (Dablanc & Browne, 2020). The largest warehouses are being moved to the distant outskirts though they continue to be sited near motorway interchanges so they enjoy a good level of accessibility. And so dispersal forces are at play on a metropolitan scale, while on the very local scale of the motorway interchange, the polarization effect comes back into play in the form of the agglomeration of warehouses within logistics platforms.

The gateway as an interface for trade, metropolization, and transport

Gateways are at the interface of three "spheres" that operate according to their own logic: international trade, international transport, and metropolization. Gateways are what connect these (Figure 1.2). The internationalization of value chains hinges on metropolization. The growth in international trade arising from it depends on the efficiency of international transport. Through massification, and as a result of

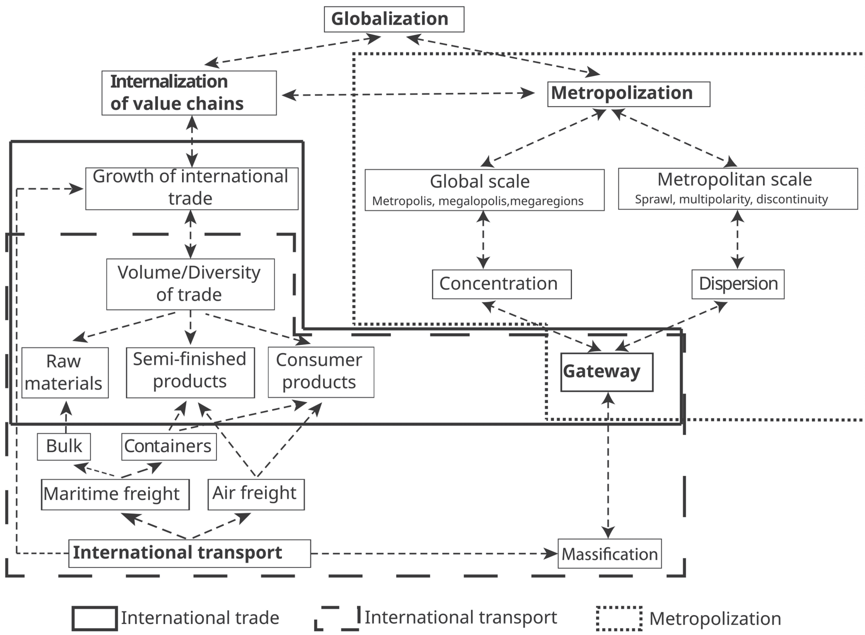

Figure 1.2 Gateways at the interface of three spheres: transport, trade, and metropolization.

containerization especially, international transport has in return fuelled the polarization effect and, consequently, metropolization.

Gateways are the endpoint (or departure point) of international flows, which are split up on a metropolitan scale. Gateways create polarization on a global scale while guaranteeing the splitting up and fine-grain distribution of international flows on a local scale.

Gateways operate as a system comprising the different layers that allow international trade flows to be organized: land transport; telecommunications infrastructure; logistics infrastructure, in particular warehouses; and logistics services offered by transport and logistics companies. Gateways have as their central infrastructure a seaport and/or an international airport, from which international flows are organized via maritime or air routes. This central infrastructure interconnects with the various inland transport networks.

Typology of metropolitan gateways

Distinguishing criteria

Metropolitan gateways have different geographical configurations. I propose three criteria for distinguishing them.

The first criterion: The metropolitan gateway's organization is dependent on the distribution of people and activities. This gateway is integrated into urban networks that create "a dynamic of interdependence" (Pumain, 1997) between cities. These networks have various geographical configurations. At one extreme, the gateway might belong to an "isolated" metropolis whose contacts with other major world metropolises are distant. At the other, it might belong to an urban network comprising cities of differing sizes.

The second criterion: The metropolitan gateway's hinterland directly depends on this urban network's geographical configuration. The hinterland of an "isolated" metropolis is therefore confined to the metropolitan area's hinterland. Conversely, a polycentric urban network comprising several cities that are relatively close to one another helps to create a local regional hinterland whose wealth directly correlates with the wealth of the cities that the network comprises. The cities' close contacts with one another make the hinterland continuous. If the urban network extends over a truly vast regional aggregation, with which the cities maintain priority contacts, the hinterland will have a megaregional dimension.

The metropolitan gateway can also serve faraway urban networks comprising distant cities that do not directly belong to the nearby regional hinterland. In addition to the nearby hinterland, discontinuous hinterlands are served by the metropolitan gateway (Notteboom & Rodrigue, 2005, 2022; Notteboom, 2010). This discontinuous hinterland is connected to the gateway by a rail or river land bridge. The massification of traffic in the nearby hinterland is an important instrument for establishing these land bridges to inland destinations further afield. The hub function also helps these distant, discontinuous hinterlands to be served. Short- or medium-haul feeder shipping lines or air routes that are interconnected with intercontinental shipping lines or air routes serve these markets, which are not located in the nearby hinterland. By serving these discontinuous hinterlands, gateways take on a continental dimension.

The third criterion: The location of the central infrastructure within this urban network, whether it is a port or airport, affects the role that maritime shipping plays in the gateway. The airport will routinely be located within the immediate vicinity of the heart of the metropolis – from a few kilometres away to a few tens of kilometres away in the case of the most distant ones. As a result, it derives maximum benefit from centrality and accessibility effects, which are essential when it comes to delivering high value-added products that entail a quick and reliable door-to-door service. Conversely, if the metropolis is not sited on the coast or on a river that is accessible to seagoing vessels, the seaport will not necessarily be located in it. If this is the case, the metropolis will rely on a seaport located in a port city some distance away from the metropolis. This port city will often simply be a technical appendage of the metropolis, which by definition is where command functions are concentrated. The way in which inland transport networks are organized tends to compensate for the maritime city's relatively peripheral location. Indeed, to preserve centrality and accessibility effects as much as possible, motorway, rail and/or river corridors between the port and the metropolis will have been built based on the volume of flows. The maritime dimension therefore varies greatly from gateway to gateway. It will be strong if the metropolis is on the coast, and both the port and the airport are sited there. It will be much less strong if the port city is separate from the metropolis.

Four basic configurations can therefore be distinguished: the maritime metropolis, the maritime- or land-dominant metropolized inland corridor, the metropolized maritime conurbation, and the metropolized maritime range. These configurations are basic because they can be combined with each other to form much more complex aggregate entities.

The maritime metropolis

Definition

This corresponds to a basic geographical configuration. A key characteristic of the maritime metropolis, located on the coast, is a nearby hinterland that merges with the metropolis itself (see Figure 1.3). Metropolitan activity creates traffic and contacts with the rest of the world without the need for any other direct link with nearby inland cities. In certain respects, this metropolis is self-sufficient. It lives off its distant foreign contacts alone, whether these go through sea and air or land channels.

The port and the airport, located in the metropolitan area, provide its contacts – for passengers and goods alike – to the rest of the world. A hub function may or may not complement port and airport activity so as to redistribute flows over intermediate, regional, or national scales. A land bridge may provide links with a discontinuous hinterland.

The polarization exerted by the metropolis is due both to its demographic weight and, even more so, to its GDP and its place within value chains. But the importance of the maritime and air networks that it polarizes also contributes to its reach. A hub function makes it a major node in global maritime and air contacts.

In this first configuration, the maritime metropolis alone channels concentration and dispersal forces on different scales (see Table 1.2).

Geography

In the past, city-states such as Venice and Genoa were the embodiment of these "pure" maritime metropolises connected to the rest of the world. To use Fernand Braudel's term, they generated their own "world space." At one time or another in their history, Hanseatic and Baltic cities (Lübeck, Hamburg, Bremen,

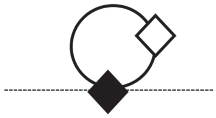

Figure 1.3 The maritime metropolis.

Table 1.2 The forces present in the metropolitan gateway.

Scale	*Concentration*	*Dispersal*	*Factor*
Global	++		Market area
Metropolitan areas		++	Land prices
Local	++		Accessibility via a motorway interchange

Copenhagen-Malmö, Stockholm, and Helsinki), Mediterranean cities (Athens-Piraeus, Genoa, Marseille, Barcelona, and Valencia), and Atlantic cities (Lisbon, Bordeaux, and Nantes) lived more off their maritime and commercial contacts than they did off their links with their hinterland.

The gateway function serves the affirmation of metropolises. Cities that came about as a result of European colonization initially corresponded to this basic form of the maritime metropolis. To be sure, they were a first point of entry to the continent, but they were so while primarily maintaining priority maritime contacts with a distant exterior – in this case, the colonizing countries' seaports. In the countries of the English-speaking New World, these cities were originally built around a bay that was often spanned by a metal suspension bridge. Throughout their history, and even today owing to their location, this function of maritime metropolis permeates these cities. Now, however, cities such as New York, Sydney, and Melbourne belong to more complex urban networks. This is also true of developing countries' maritime metropolises. But unlike their counterparts in rich countries, the traffic passing through their ports or airports does not put them at the top of the global hierarchy. They are in the midst of an urban explosion, and, very often, they have to work with port or airport facilities that are unfit for the flows they need to process. Congestion is often the norm, as the maritime metropolises of the Indian subcontinent, South America, and the West African coast show.

East Asian states' integration into globalization thanks to rising growth rates was partly based on the planned emergence of maritime metropolises. Ports and airports, associated with industrial zones where manufacturing takes place, have been used by these states within the framework of proactive policies aimed at opening up their economies to the outside world. They have been two major tools for creating accessibility vis-à-vis the rest of the world. Having moved up value chains, some now have a global reach. Singapore continues to embody this archetype of the maritime metropolis, maintaining only weak contacts with its hinterland. The other Asian maritime metropolises are now part of more complex urban networks, mirroring the maritime metropolises of the English-speaking New World.

Some states are trying to reproduce this Asian model, in particular the Gulf petro-monarchies as they attempt to anticipate the post-oil era. In promoting Dubai as a world-class city-state, the United Arab Emirates is an almost caricatured example of this. Its development of a global air and maritime hub on the back of both first-rate infrastructure and, even more so, the massively subsidized expansion of the Emirates airline and the port-handling company Dubai Ports (DP) World supports this strategy.

The maritime- or land-dominant metropolized inland corridor

Definition

More generally, port cities maintain contacts with the cities in their hinterland. They have a prime location: at the mouth of a river, at the upper end of an estuary (in the case of the oldest port cities), at the mouth of an estuary (in the case of the more recent ones), or near a delta. Rivers are the linear axes that have historically prevailed as a site for establishing cities on.

An urban axis located along a river forms an inland metropolitan corridor owing to the density of contacts between its cities. These contacts exist on multiple levels: agriculture, industry, and services. They comprise material and intangible flows. Material flows are supported by road, rail, and river networks. They are what make the corridor visible. But intangible flows of communications and finance, invisible by definition and delivered over the internet and its fibre-optic cables and servers, are just as fundamental to the corridor's functioning.

With a port city as its egress, the corridor takes on a maritime dimension. The port connects the corridor with the rest of the world. The corridor corresponds to the port's nearby hinterland – that is it is not only the axis itself but also the zones of influence of the cities within the corridor. Each city in the corridor links to as many nodes as possible to reach more distant destinations and connect the nearby hinterland with more distant ones (with which this nearby hinterland is not contiguous) via a land bridge.

This metropolitan corridor is predominantly maritime when the port city is the largest city in the corridor. It is predominantly an inland corridor when the city where command functions are concentrated – this will often also be the city that has the largest population – is located inland. The airport will be located in this city (see Figure 1.4).

In this configuration, concentration and dispersal forces are exerted over each urban area; these areas are distributed throughout the corridor. These forces are strongest in the corridor's most important cities. The organization of concentration and dispersal flows is complex. Several points along the corridor are able to play this role, a situation that promotes competition between logistics operators. But the prerequisite massification requires the number of points playing this role to be limited.

Geography

In North Europe, the largest cities are primarily located inland and connected to the sea by rivers. The head of the maritime corridor can be complex here. Historically, ports have constantly migrated downriver over the centuries to adapt to the

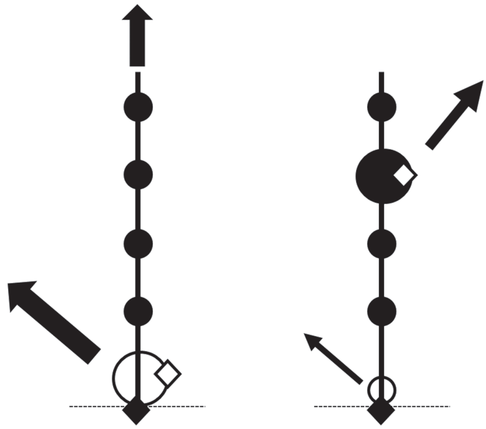

Figure 1.4 The maritime- or land-dominant metropolized inland corridor.

ever-larger proportions of ships and industrial infrastructure. Port facilities creep towards the sea to obtain better maritime accessibility. Rotterdam is a good example of this. But new port cities can also emerge. This gives rise to the classic model of a pair of port cities on an estuary. The oldest city is located at the upper end of the estuary. Marking the boundary between maritime and river transport, reloading is performed here. The city at the mouth of the estuary, which will often have originally been created for the strategic purpose of accommodating a navy, will concentrate large ocean-going traffic. By definition, accessibility between it and the hinterland is more difficult. Le Havre was created in 1517 at the mouth of the Seine estuary, 80 km downriver from Rouen. Saint Nazaire's port facilities were developed during the Second Empire because large-tonnage ships could no longer reach Nantes. Bremerhaven, at the mouth of the Weser and under a 100 kilometres from Bremen, and Tilbury on the Thames came about under similar circumstances. Far from coming to an end, this shift continued in the twentieth century to deal with the development of oil shipments and then container traffic, which require high draughts. Examples here include Vlissingen on the Scheldt, Wilhelmshaven, Cuxhaven at the mouth of the Elbe, and also Felixstowe and the DP World London Gateway in Corringham on the Thames, not to mention Zeebrugge, which was created to restore a seaport to Bruges and is now Antwerp's outer harbour.

In Europe, the Rhine forms a corridor that is exceptional because of its length and the density of traffic along the axis and because it allows the extremely vast hinterland of Germany's Rhineland, which has a very dense urban network, to be irrigated. Its maritime head is unusually complex. It is made up of the influential urban aggregation of the Randstad, which continues as Antwerp, Ghent, and Zeebrugge. This head in itself forms a metropolized maritime conurbation (see The metropolized maritime conurbation). This corridor has very tightly interwoven maritime and inland dimensions.

Elsewhere in the world, a predominantly maritime and land corridor of this kind is clearly being set up in China along the Yangtze River from Shanghai to

Chongqing, or even as far as Chengdu. It connects a metropolized coastline around the pairing of Shanghai and Ningbo, which are two of the largest ports in the world, to very important inland cities (Veenstra & Notteboom, 2011; Wan & Luan, 2022). In North America, although the St. Lawrence–Great Lakes corridor penetrates very deeply inland, it is clearly less influential than the previous two cases. The urban network along the St. Lawrence corridor is not very dense. Furthermore, Chicago and Toronto, two of the major inland cities, depend very little on this waterway for their contacts with the rest of the world.

Other metropolized corridors are geographically smaller and ultimately quite rare. However, they are capable of dense traffic concentrations owing to the size of the cities located there. The axes of the Thames and the Seine provide two good examples. They are commanded by London and Paris, the two most influential inland urban areas in Europe. They are predominantly land-based axes.

The Beijing–Tianjin axis is an example of another predominantly land-based corridor, but its backbone is not a river. It is limited to one port city, which is the inland capital's nearby maritime connection. In Malaysia, Port Klang plays this role for the capital, Kuala Lumpur, at the same time as serving as a transshipment port on the Strait of Malacca.

The metropolized maritime conurbation and the metropolized maritime range

Definition

A final type of urban network is characterized by its concentration of cities along and immediately behind the coast. The cities' proximity to one another creates an urban quasi-continuum and gives rise to a maritime conurbation (see Figure 1.5). This conurbation will be totally maritime if its main city or cities are coastal and have ports. It will have an inland facet if the conurbation's main city is inland. Where this is so, the international airport will be located in this inland metropolis.

In a final variation that is simply an extension of the maritime conurbation, there will be a dense spread of several port metropolises along the coast, creating an urban quasi-continuum. These metropolises will form a metropolized maritime range (see Figure 1.6).

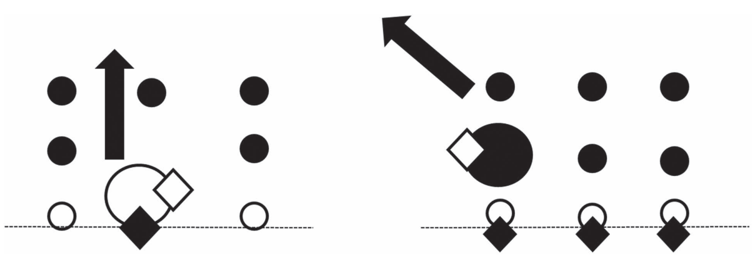

Figure 1.5 The maritime- or land-dominant maritime conurbation.

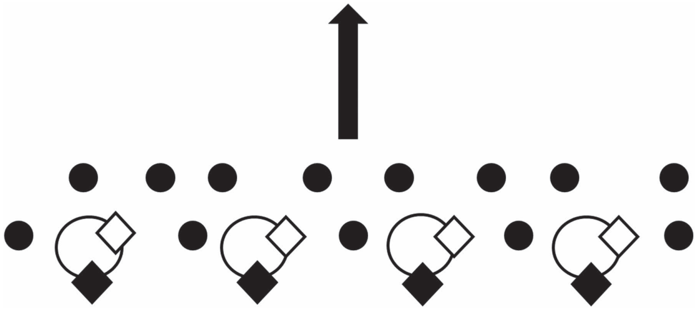

Figure 1.6 The maritime range.

As is the case of the inland metropolized corridor, the conurbation and the maritime range can be linked to a more distant and discontinuous hinterland via a land bridge.

In these two configurations, concentration and dispersal forces are distributed between the different urban centres, a dynamic that does not necessarily align with massification.

Geography

The Randstad embodies the archetype of a metropolitan maritime conurbation. The density and proximity of the cities it brings together in a continuum and quadrilateral – Amsterdam, The Hague, Rotterdam, Dordrecht, and Utrecht – make it a true conurbation. Its main port is in Rotterdam, but Amsterdam's port also plays an important role, and Schiphol international airport is located in the latter city. The Randstad is also the head of the Rhine corridor.

In a similar vein to the Randstad, other maritime conurbations have continued to grow throughout the world. On the West Coast of North America, the conurbations of Los Angeles–Long Beach, the San Francisco Bay Area, Seattle–Tacoma, and Vancouver combine important gateway functions with other metropolitan functions. Their seaports are all gateways to the continental inland because of the scope of North American railways, which largely converge on Chicago.

East Asia's development is reflected in the rise of these kinds of maritime conurbations. In South Korea, there are two: Ulsan–Busan–Changwon and Seoul–Incheon. The heads of China's conurbations of this type are the Pearl River Delta (Wang & Slack, 2000; Liu et al., 2013) and Shanghai–Ningbo (Wan & Luan, 2022). The latter combines two of the most important ports in the world, and via the Yangtze, it also commands a developing inland corridor.

The metropolized maritime range is simply an extension of the maritime conurbation on a much larger scale. There are two very specific – and also well-known – cases of it in the world: BosWash in the United States, which Jean Gottmann highlighted in the 1960s (Gottmann, 1961), and the Japanese megalopolis encompassing Tokyo–Yokohama and Osaka. The major transport corridors they are based on are not inland corridors but instead run parallel to the coast, linking littoral cities together (Rodrigue, 2004). BosWash's cities have also developed increasingly strong contacts with inland cities over time. They form the bridgeheads of inland corridors that are appended to the metropolized maritime range.

The North European maritime range, running between Le Havre and Hamburg, is historically a discontinuous succession of metropolized inland corridors. But the densification of maritime and land exchanges along this axis, a result of European integration, is gradually turning it into a metropolized maritime range.

Conclusion

A gateway forms a system. Its main elements are seaports and airports. Connected to it are the transport and logistics infrastructure used by transport and logistics companies to provide services to their customers. In very concrete terms, the gateway makes it possible to organize the flow of goods by influencing two essential factors: the concentration and the dispersal of flows. Gateways have a privileged location within metropolises because transport and logistics infrastructure and services as well as international trade flows are concentrated in metropolises. Gateways are the sites where this concentration and this dispersal of flows are organized.

Gateways' geographical configurations vary according to how urban networks are organized, what the characteristics of the hinterland are, and whether the gateway is predominantly maritime- or land-based. I have highlighted four basic configurations: the maritime metropolis, the maritime- or land-dominant metropolized inland corridor, the maritime- or land-dominant maritime conurbation, and the maritime range. These four basic types can be combined ad infinitum: a metropolized inland corridor can have a maritime conurbation at its head, a maritime range can be extended by several metropolized inland corridors, and so on.

Future research is needed to show that the processes by which goods flows are concentrated and dispersed differ according to geographical configurations. These different configurations undoubtedly require governance systems to be adapted to them, with consideration given to the specificity of these processes as well as the differing distribution and weight of actors – in particular logistics actors – across the configurations.

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2 Intermodal corridors and sea–land logistics

What role should regulation play?

Francesco Parola

Introduction: breakthroughs and challenges in maritime logistics

Sea–land logistics are undergoing a profound transformation due to the changes occurring in the organization of logistics chains, including the vertical integration of ocean carriers in port and intermodal operations as well as the growing presence of financial actors. In addition, the recent pandemic caused tremendous bottlenecks in global logistics chains, resulting in much higher freight rates and severe delays in maritime and hinterland transportation. In light of this general trend, the war in Ukraine must be viewed as an additional threat to the resilience of supply chains across Europe.

In this introduction, we aim to depict the major trends that have characterized maritime logistics over the last decade in order to understand the role that can be played by regulation in improving the functioning of individual sub-markets.

First, in maritime transport, it is becoming increasingly common for shipping lines to pursue economies of scale. The standardization of full containerships, coupled with the deployment of bigger vessels, has brought about an apparently never-ending upsizing trend. The maximum size of container vessels is now over three times bigger than in the early 2000s due to the widespread adoption of 24,000 TEU vessels by major shipowners. This choice, motivated by the need to reduce transport costs per unit, has had an impact on the operational efficiency and costs of port and inland operations.

Such a dramatic rise in vessel scale has not been followed by a corresponding growth in port terminals and inland means of transport (e.g. trucks, trains). Only a handful of Europe's busiest ports – such as Rotterdam, Antwerp, Valencia, and Piraeus – have been able to accommodate such huge "call sizes." To do so, they have had to build new mega-terminals with a capacity of two million TEUs or more. The impact of big vessels has been even more disruptive in road and rail transportation logistics. While the size of trucks has not changed significantly, cargo train capacity has increased along certain stretches of railway within the Trans-European Transport Network (TEN-T) corridors, where train lengths of 750 m and 2,000/2,500 tonnes of capacity are permitted. As a result, rail transportation has achieved economies of scale in terms of train capacity, which have remained relatively stable in numerous ports and inland corridors, leading to severe

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operational bottlenecks. In this context, infrastructural disasters such as the Rastatt incident in Germany (rail) and the Morandi bridge collapse in Italy (motorway) are a clear illustration of a significant lack of logistics resilience. The growing asymmetry between the scale of vessels and trains is exacerbating these major concerns in maritime supply chains.

Second, the economies of scale in assets have led to the formation of bigger logistics players of a suitable organizational and financial scale. Market concentration in container shipping is constantly rising: in 2005, the market share of the top five carriers was below 40%, whereas it now stands at approximately 65%. Similarly, in container terminal operations, the diffusion of port governance reforms worldwide (liberalization and privatization) and the attractiveness of the industry (high demand growth rates) have led to the internationalization and concentration of the sector (Ferrari et al., 2015). The top five players in the industry now handle over 30% of global container throughput, thus making them powerful contractual counterparts to ocean carriers. In addition, some big carriers (e.g. MSC/TiL, Maersk/APM Terminals, China COSCO, CMA CGM) have undertaken increased vertical integration in port and onshore logistics activities, thus obtaining an even higher bargaining power across the supply chain. Overall, the much bigger organizational and financial scale achieved by ocean carriers and terminal operators is creating unique challenges for port authorities, which are the public entities responsible for leasing out port land for commercial exploitation. The major bargaining power of private logistics players, who are able to shift huge amounts of cargo from one port to another and make quick decisions over whether to invest or disinvest in port facilities, is putting unprecedented pressure on port authorities, which ultimately risk being marginalized in the decision-making process on port development. This delicate public versus private "balance of powers" between international private firms and local port authorities is one of the major challenges policy makers and public managers now have to face (Dooms et al., 2019).

Third, the international spread of competition across maritime logistics chains, triggered by the standardization of transport units and the effects of trade globalization, has facilitated the growth of gateway ports capable of competing for contestable hinterlands. Indeed, containerization and intermodal transport have created a profound discontinuity in logistics chain development, widening port hinterland boundaries and leading to a paradigm shift from captive to contestable hinterlands.

These transformations have produced fiercer onshore competition for cargo capture and profoundly reshaped the spatial competitive boundaries of ports located within the same range (e.g. Rhine–Scheldt delta, West–Med range, Adriatic range) and also, to some extent, in opposing ranges, such as Northern versus Southern range ports in Europe. Some gateways have been "elected" as commercial leaders for their superior operational reliability, efficiency, and effectiveness in hinterland penetration. As a result, the erosion of traditional hinterland paradigms has led to higher inland market contestability and the modification of both the size and shape of hinterlands. Notteboom and Rodrigue (2005) argued that hinterlands became characterized by more discontinuous physical boundaries as the most competitive ports, exploiting a significant comparative cost-advantage with respect to their peers, were able to capture cargo from distant markets, even in the captive area of other ports ("island formation"). This means that the traditional perspective based on the concept of distance decay cannot be used to explain the inter-port competitive dynamics that shape modern hinterlands. Today, a port's competitiveness is determined by factors such as the effectiveness of its road and rail connections along TEN-T corridors and its relationship with inland terminals. Indeed, efficient and reliable inland supply chains are now essential for a port's commercial success, and physical attributes alone are no longer sufficient (Parola et al., 2017).

Finally, recent years have seen spectacular "financial margin" shifts among the actors of the maritime logistics industry. The severe slowdown caused by the COVID-19 pandemic was followed by a sudden and accelerated recovery, which led to a positive trend in demand that has exceeded supply capacity. The demand surge, combined with port congestion and COVID-19 restrictions, has had a direct impact on maritime supply. The COVID-19 pandemic demonstrated how capable ocean carriers have become at managing the market's supply of cargo capacity by "cutting down" on capacity during the trough of the pandemic and then ramping it up when demand rebounded sharply. As a result, freight rates soared, mostly along the major routes, reaching unprecedented price levels (up to five to seven times higher than traditional freight rates). Shippers suffered from a lack of commercial bargaining power as shipping lines became the undisputed "price makers" thanks to the global shipping alliances' control over capacity (available slots, schedule, and speed) and the shortage of containers in circulation. As a result, ocean carriers, which traditionally generated poor financial margins, reached estimated profits of over $150 billion dollars in 2021, a truly unforeseeable figure after a decade of economic troubles. Although this market trend will be temporary, it is very hard to predict the timing of the next changes, as well as what the future "new normal" will look like in the industry. Undoubtedly, the global resilience and logistics flexibility of this sector require substantial improvements. It is also necessary to address how the value generated in the industry can be distributed more evenly among actors, as this will have an impact on the price of finished products for end consumers.

Rail transport as a logistics enabler for port growth

Hinterland transportation is a crucial link within global maritime supply chains. Although it typically represents just 10–15% of the overall door-to-door logistics distance covered, the associated costs can account for as much as 80% of the entire chain. The port is the physical location where the economies of scale generated by maritime transport encounter logistics disruption, as sea traffic flows are fragmented across the hinterland where the cargo's origin/destination is located. The scale asymmetry between maritime (vessel) and inland (road and rail) means of transport is the main reason for the much higher costs per tonne/kilometre in hinterland transportation compared to in maritime transportation. The situation may be slightly different for those ports served by barge, but the "scale ratio" (barge versus ship size) is still largely in favour of marine vessels in this context too. Besides the scale effects of transport, there are also negative forces that increase inland transport costs, as they constitute “frictions” to the transit of cargo flows and reduce hinterland contestability (Ferrari et al., 2011). These frictions include issues such as a lack of capacity in port and onshore infrastructure; higher port costs; and inefficient, expensive, and unreliable road and rail connections, all of which have a negative impact on port development in inland markets, potentially diverting traffic flows to other logistics corridors or competing ports.

In this context, in order to widen their geographic scope in inland markets, ports have to establish high-capacity and efficient logistics corridors. Other than inland navigation, which is only an option for a limited number of ports, rail transportation has the potential to become the primary strategic tool for increasing traffic volumes and expanding hinterland boundaries. As future TEN-T corridors are envisioned as having an upgraded network with superior service performance, rail transport could offer good economies of scale, capable of adjusting, to some extent, to the pace of fast-growing maritime volumes (“call size”).

However, in the current industry landscape, rail transport has several drawbacks and weaknesses that may limit its competitiveness quite considerably. Figure 2.1 depicts a typical “vicious cycle,” which is particularly prevalent in certain Mediterranean contexts, thus making rail transportation less appealing than road transport.

The initial step of the cycle is fed by the “inertia” caused by demand levels. The modal split largely favours road transport, which is far more flexible and cheaper. Consequently, the demand for rail services is irregular over time, unbalanced, and,

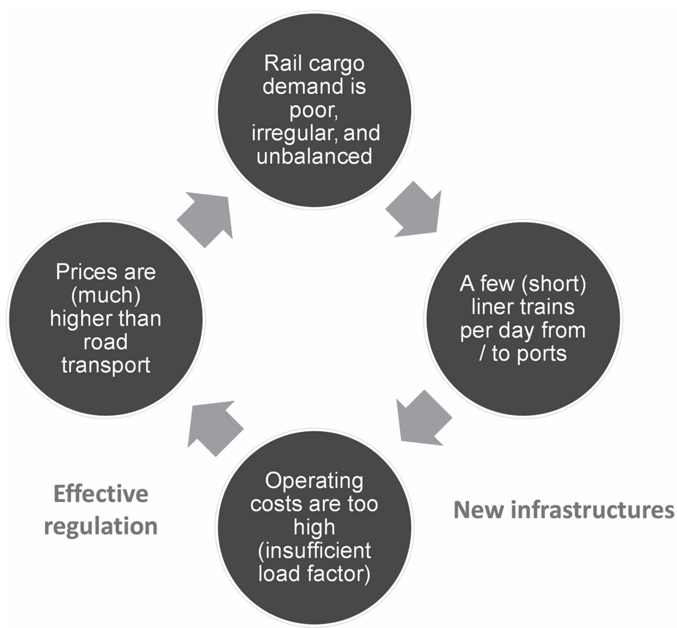

Figure 2.1 The “vicious cycle” characterizing the rail cargo industry.

Source: author’s own elaboration.

in many cases, quite modest in terms of total volumes. Rail service supply is characterized by a small number of trains during the week, with a limited capacity (number of wagons), both for technical (low performance of the rail network) and commercial reasons (achievement of an acceptable load factor). As a result, operating costs are typically rather high compared to those for road transport due to the modest economies of scale achieved. Inevitably, rail operators are forced to set prices that are not competitive relative to trucks costs, leading to low demand. This closes the loop, which requires dismantling in some way. In this regard, additional investments in infrastructure and the introduction of suitable regulatory measures could represent path-breaking actions for both long- and short-term progress. Investments could improve the quality of existing infrastructure (e.g. technological upgrade, bypasses) and also create greater capacity by activating new railway lines or stretches. In addition to this, regulation can provide economic measures for incentivizing rail services along low-capacity and underperforming rail paths. For instance it would be possible to reduce train path charges or to deliver economic incentives to operators establishing pioneering rail services from/to ports and logistics centres. These two streams of action are both important, and they can have an even more positive outcome if they are coordinated together.

As regards rail investments, it is worth giving some attention to the influential set of projects included in the TEN-T network at the European level. The Trans-European Transport and Energy Networks (TENs) policy was established in the 1990s, with the goal of constructing high-capacity and high-performing railways that connect all EU member states in an intermodal manner (Reis et al., 2013). In particular, the core network includes the most strategically important sections, and it is based on a corridor approach. Overall, nine corridors connect EU states from north to south and from east to west. In the medium and long term, the improvement of railway infrastructure will lead to significant growth in rail transport volumes within corridors, thanks to an increase in rail capacity and the superior performance achieved (i.e. 750 m train length, 2,000 tonnes and above, along with upgraded tracks and minimum ruling gradients at mountain crossings). The gradual introduction of a higher technical performance is intended to attract additional demand through lower operating costs per TEU/km, higher service frequencies, and reduced transit times. The challenge that now needs to be addressed, both from an operational and a financial point of view, is to offer homogeneous standards from origin to destination, along a seamless and efficient "continuum" of rail infrastructure.

Economic regulation in sea–land transport: the Italian experience

In this section, we explain the role and the mechanisms of economic regulation in shaping maritime logistics chains and draw on some insightful empirical evidence from an Italian case study. A key observation is that regulation is a powerful tool for ensuring smoother, more transparent, and efficient operations across a number of industries. Regulated companies and public entities should therefore not view it as an additional administrative burden on top of their "normal" business activities.

Figure 2.2 summarizes the main areas of economic regulation intervention, along with some key objectives to be pursued. (1) First, regulation has to ensure transparent, equal, and non-discriminatory access to transport infrastructure. This is highly relevant in contexts of natural monopolies like port terminals, motorways, airports, and railways, as the awarding authority (e.g. port authorities, central government, regions) has to select the (best) concessionaire for the economic and commercial exploitation of such logistics assets. The selection criteria should be properly defined in advance, and the awarding procedure has to target the concessionaire offering the best compromise in terms of planned investments and expectations of future demand. (2) In addition, regulation has to provide adequate mechanisms for the awarding authority to be able to supervise the concessionaire's behaviour in terms of managerial and financial compliance with respect to the approved business plan. Indeed, the concessionaire should make proper use of the (public) assets managed under the concession agreement, pursuing an optimal and efficient use of the infrastructure in accordance with the planned traffic mix and the technological characteristics of the facilities. (3) Another important "building block" of the whole regulatory framework are pricing mechanisms. Under monopolistic conditions, pricing criteria should be grounded on cost-based and user-pay principles in order to limit/moderate the financial margins of the concessionaire/operator. A major goal of regulation in public services/infrastructure is to iron out those managerial inefficiencies that commonly arise in situations where a lack of competition allows the incumbent to enjoy economic rents. In this regard, regulatory authorities may be called upon to set the maximum (allowed) financial

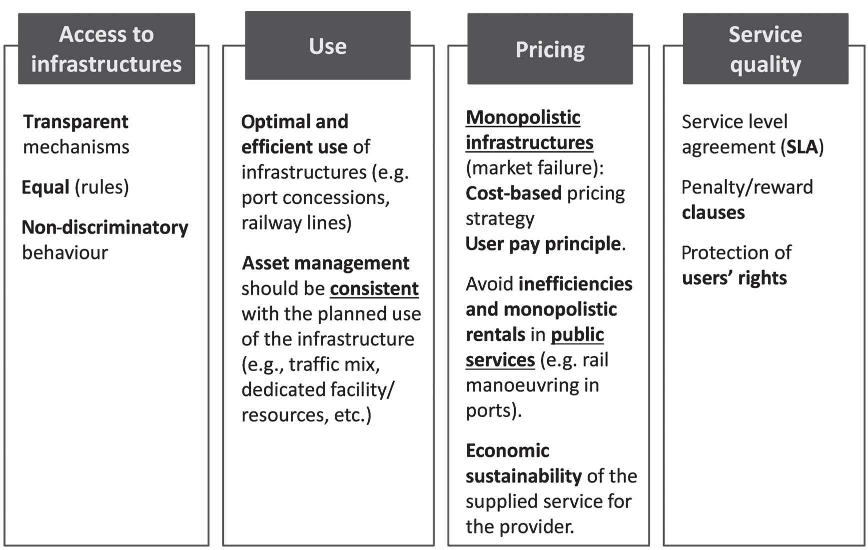

Figure 2.2 Regulatory milestones in transport.

Source: author's own elaboration.

margins (e.g. by determining the weighted average cost of capital [WACC]) that can be granted to concessionaires to reward private investments made during the concession period. Ultimately, regulators should also ensure the economic and financial sustainability of the regulated activities by carefully monitoring demand levels, cost-efficient structures, exogenous events that may impact the firm's profits, and so on.

(4) Finally, economic regulation has to manage service quality levels in order to protect customers from a decline in quality standards. This area of intervention is closely associated with the need to manage infrastructure in an efficient and optimal manner. Regulators can either provide incentives or establish mechanisms for the introduction of service quality agreements between the parties involved in the transport business. Further to this, a "suite" of penalty/reward clauses could be included in the concession agreements (e.g. motorways, port terminals) and in the contracts for the assignment of transport services (e.g. regional rail services, local public transport). Regulatory authorities are also typically responsible for protecting users' rights, both in B2B and B2C transactions (e.g. service quality, price moderation), acting as a superordinate and independent actor "set apart" from the involved business parties. The degree to which users can be protected and the authorities' competence to directly intervene depend on the EU regulations related to individual transport modes and the specific legislative framework of each country.

In general terms, the substantial "bargaining power" of the regulator in case of misapplication of the given rules or violation of the obligations of transport operators is rather "variable" across transport modes. Typically, the regulator has the authority to intervene, such as by applying sanctions to regulated firms (e.g. rail infrastructure manager), when its own regulatory measures are not fully respected. However, when the awarding authority (e.g. transport ministry, port authority) does not include specific obligations in the contracts signed with the concessionaires, the regulator's power becomes significantly less effective.

Insightful empirical evidence from the Italian context sheds light on the role played by regulation in transport industries, and particularly in maritime logistics, including ports, railways, and motorways. The Autorità di regolazione dei trasporti (ART) (Italian Transport Regulation Authority) is a fully independent authority responsible for making autonomous decisions on recruitment at all levels, organization, and operation. It is exclusively funded by contributions from regulated companies. Decisions are adopted by a board composed of three members acting as a collegiate body. ART's regulatory decisions ("resolutions") are preceded by a public consultation process involving industry stakeholders. In some areas, ART's main function of ex-ante regulation is complemented by an advisory role (e.g. motorways).

ART's competences span across all transport modes and encompass the regulation of access to infrastructure and services as well as passengers' rights. This authority adopts measures to ensure transparent, equitable, and non-discriminatory access to public infrastructure and services and also sets the criteria of the infrastructure charging system (e.g. train path charges, motorway tariffs). Moreover, ART prescribes the regulatory accounting systems and imposes separation obligations pertaining to accounting, corporate governance, and firm ownership. It monitors regulated entities' compliance with ART's regulatory measures in relation to the cost-effectiveness of the pricing system, efficiency targets, profit margins, service quality levels, and so on. ART enforces its decisions and monitoring activities by imposing monetary sanctions and potentially enforcing specific behaviours.

In addition to this general framework, the regulatory body has to incorporate the legislative and industry aspects specific to each mode of transportation into its actions. In this regard, Figure 2.3 reveals the institutional positioning of ART across the sub-sectors of the maritime logistics industry. Essentially, its competences are framed within EU directives, regulations, and general principles as well as the national laws setting the rules in the individual transport domains. More specifically, ART is entitled to intervene as a regulator, thanks to the contents of its constitutive law. This enables it to create ad-hoc regulatory measures and monitor stakeholders' compliance.

In each sub-sector, the business structure and the related competences of ART differ from each other. Hence, regulatory principles and the actions/decisions of this authority need to be consistent across each industry, while also being "adaptive" by recognizing the specific features and key economic drivers of various transport modes. Broadly speaking, ART is responsible for regulating the business activities of both infrastructure managers/landlords and operators/concessionaires in ports, railways, and motorways. In ports, port authorities act as landlords awarding

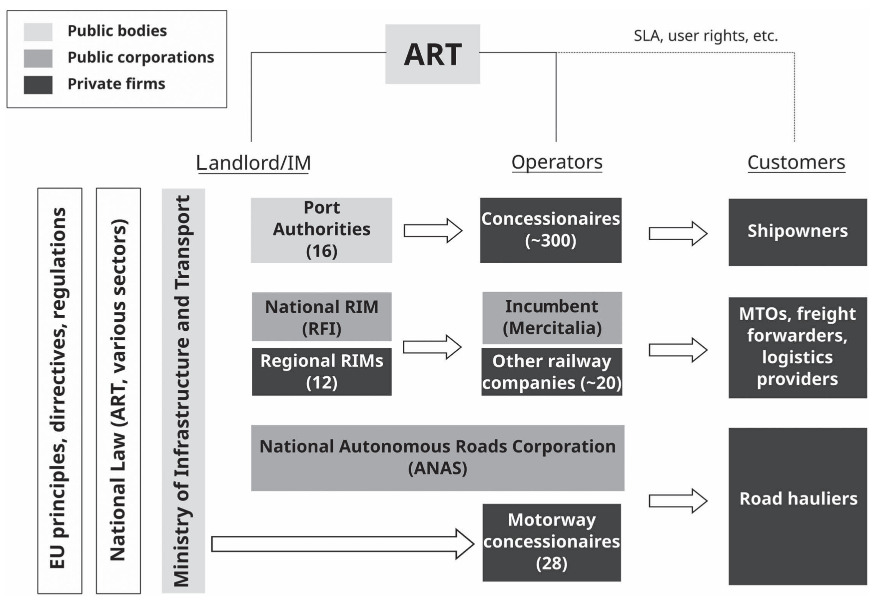

Figure 2.3 The positioning of ART in the regulatory framework of ports, railways, and motorways. *Note*: RIM = rail infrastructure manager.

Source: author's own elaboration.

portions of land to private concessionaires for undertaking cargo handling operations. In the rail industry, there is a major national infrastructure manager (Rete Ferroviaria Italiana) (RFI) that takes care of the maintenance, development, and day-to day management of over 16,000 km of railways. To carry out their work, railway operators need to obtain capacity in terms of train paths from RFI by paying charges. In this regard, capacity allocation, traffic mix balance, circulation management, and pricing strategy are among the most critical "regulatory" decisions in the hands of the infrastructure manager. The infrastructure manager's choices have a significant impact on the degree of rail liberalization and on the equality and non-discrimination of access to infrastructure.

In the motorways sector, while a portion of the network (non-toll roads) is managed directly by a state-owned company (ANAS), the majority of motorway infrastructure is managed by private companies that have been granted concessions. These concessions allow private firms to manage a network of motorway infrastructure ranging from a few kilometres up to 3,000 km, as in the case of the toll road operator Autostrade per l'Italia (ASPI). The national awarding authority is the Italian Ministry of Infrastructure and Transport. In general terms, the regulatory role of ART has to be exercised in conjunction with the ministry's competences, which has broad monitoring power over the transport infrastructure and, in the case of motorways, also directly acts as a landlord.

By addressing the current state-of-art of regulation across transport modes, a rather heterogeneous framework emerges (Table 2.1).

The first group of regulatory issues (i–iv) illustrate the industry's level of maturity in terms of liberalization, privatization, and international openness. Despite the port governance reforms in the 1990s and the liberalization process, ports still present a moderate level of regulatory maturity, and only a limited number of new firms have been able to access the market. Nonetheless, over the last decade, the industry has witnessed the arrival of some international entrants with financial backgrounds. The rail sector is probably the most mature from the viewpoint of regulation, but its degree of international openness is still modest. The motorway sector has been privatized over the last 20 years, but regulatory mechanisms (see Law no. 130/2018) have only recently been introduced by ART, impacting both ongoing and new concession agreements (cost-effective pricing, cap on profit margins, etc.).

Similar considerations can be drawn regarding the achieved regulatory effectiveness in terms of transparency, equal and non-discriminatory access to infrastructure, and national harmonization of rules (v–viii). Again, ports, on average, show a higher level of entry barriers compared to the adjacent industries. In particular, port authorities across the country present heterogeneous approaches in the setting of criteria for awarding logistics assets to concessionaires and scoring submitted business proposals (e.g. bid evaluation, private investments vs. concession duration, assessment of demand forecasting) (Parola et al., 2012).

In maritime logistics, additional efforts could be made to protect incumbents and potential newcomers from the threat of market foreclosure as a result of vertical integration. In some contexts, a vertically integrated firm may be tempted

Table 2.1 State-of-art of regulation: a sectorial comparison.

Key regulatory issues/ concerns	*Ports*	*Rail sector*	*Motorways*
i) Degree of maturity of national regulation (e.g. mechanisms, stakeholders acceptance)	Low	Medium/high	Medium
ii) Degree of (actual) liberalization	Medium/high	Medium	Medium
iii) Degree of internationalization (inwards/outwards)	Rather high international opening (inwards)	Some entries by foreign rail operators (inwards)	Recent entries by mutual funds (e.g. Macquarie, Blackstone)
iv) Contestability of the industry (entry barriers, etc.)	Medium	Medium	Low
v) Managerialization of the infrastructure manager (efficiency-driven principles)	Low (PA)	Medium/high (IM)	Yardstick competition (concessionaire)
vi) Degree of transparency in the industry (market access, pricing, etc.)	Low	Medium/high	Low/medium
vii) Equal and non-discriminatory access to infrastructure (tenders, pricing, clauses, etc.)	Low	Medium/high	Medium
viii) Harmonization in the application of regulatory principles across the country	Low	High	Medium

Source: author's own elaboration.

to dominate an industry segment, excluding or marginalizing rivals in vertically related markets. This might be the case for ports, where ocean carriers have a major stake in terminal activities, as well as for the rail industry, where the national infrastructure manager, RFI, still belongs to the same group as the incumbent rail cargo operator (Mercitalia).

Looking at future developments, the regulatory framework could be improved in a number of directions. As regards the port industry, there are some public and private stakeholders asking for more homogeneous criteria at the national level for determining concession fees and the duration of concession (e.g. eligible investments), in line with the contents of the business plan. In addition, a more in-depth monitoring of the concessionaire might lead to reinforcing managerial efficiency in the use of port spaces (e.g. exploited capacity, land utilization intensity), particularly in the case of vertical integration by shipowners. Another relevant area of improvement involves the introduction of substantial forms of control and the provision of a penalty system to ensure the terminal operator's compliance with the investments and expected traffic volumes indicated in the business plan (e.g. throughput guarantees, investment schedule, occupancy levels, percentage use of terminals, discriminatory behaviour in allowing access to berths). In addition, clauses dealing with the (eventual) substantial modification of the concessionaire's "shareholder structure," as well as reward clauses (commercial performance, rail incentives, green initiatives, etc.), could be properly introduced in the concession agreement where necessary. Finally, a fair contractual predefinition of the (eventual) residual value of the concession could mitigate some economic concerns in the event of a terminal handover.

Analogously, in rail transport, there is significant room for progress. In principle, it would be possible for rail network management to achieve a higher level of efficiency by having more efficient allocation criteria for train paths and circulation management through better temporal and/or spatial separation of traffic flows (e.g. Smith et al., 2010). The charging criteria for accessing the rail network could be improved and made more sophisticated, reinforcing its association with the real costs, and even using reward mechanisms for those rail operators who book train paths for more efficient (i.e., longer and heavier) cargo trains. A rather delicate issue is that of rail manoeuvring operations in ports and inland logistics centres. Typically, these charges are quite expensive and not really "anchored" to costs: it is therefore important to improve efficiency and make pricing more competitive, as well as to promote the reduction of entry barriers to rail operators willing to join this market. This aim should be pursued with a view to reducing total transit times and improving rail service reliability.

Final remarks and recommendations

This chapter addresses the business of maritime logistics in the context of economic regulation, bringing practical evidence from the Italian maritime transport industry. Conceptual arguments on the relevance of regulation for ensuring efficient and transparent market dynamics are corroborated by anecdotal cases, offering some insightful concluding remarks.

First, in the national transport sector, there is a need for greater transparency, since transparency is not only the prerequisite for effective regulatory action but also a tool for achieving the objectives of efficiency and opening up the markets while complying with the principles of fairness and non-discrimination (e.g. Smith, 2012; Wheat, 2017). In addition to this, regulatory action should focus on fostering the integration of different modes of transport and promoting intermodal transport. This can lead to improved technical and operational coordination between carriers, achieved by defining ad-hoc regulatory mechanisms.

A second issue concerns the possibility of introducing more frequent rewarding clauses in both concession agreements and tenders for the assignment of service contracts. These clauses could help to reduce emissions, promote a modal split re-equilibrium, boost investments in innovative technologies, and improve the compliance of the concessionaire/operator with respect to the obligations contained in the submitted business proposal. To achieve these objectives, ART could facilitate the inclusion of these clauses by intervening in the actions either of the grantor or of the entrusting body.

Third, it is necessary to act synergically to minimize the areas in which there is a risk of "multi-layered regulation." The stratification of regulatory principles and measures can occur if principles and measures established by different institutions or authorities are not coordinated with each other. In some cases, such stratification of competences may generate institutional or legal conflicts among public and/or private actors. This risk exists in the port sector as there are 16 port authorities with managerial tasks and responsibilities at the local level, and the Ministry of Infrastructure and Transport and ART at the national level (endowed with regulatory and monitoring powers).

Fourth, it is important to note some of the shortcomings of the current regulatory framework. Although some steps have already been taken to improve regulations impacting port concessions, rail capacity constraints, management efficiency, road infrastructure costs, and weaknesses are still present regarding the effectiveness of "end-to-end" operations, especially in light of the unprecedented challenges imposed by intermodal chains for freight and passengers. Indeed, the current regulatory framework does not allow ART to intervene across transport modes in strict regulatory terms (e.g. setting tariff criteria, defining cost items). However, despite the current legislative context and the formal separation between transport modes, in evaluating the business plan, it would be worth taking the effects of intermodal competition into account when estimating the accuracy of demand forecasts, as well as identifying the boundaries of the so-called "relevant market." Future legislative and regulatory activity might attempt to bridge this gap, following the EU trend towards the development of intermodal corridors across nations.

Lastly, it would be necessary to intensify the use of big data to undertake more effective and conscious regulatory actions, as well as to consolidate the authority's monitoring and supervision activity, also in collaboration with the competent ministry. Without reliable, extensive, and up-to-date datasets, it is far more difficult to guarantee the principle of transparency for accessing markets. Data-driven regulation is certainly an ambitious goal, but the technological standards and the administrative paths to achieve it have long been available. In the rail sector, for example, there are already broad information web portals managed by the infrastructure manager, RFI, to which ART has access for the fulfilment of its competences. Because of the rail sector's technological maturity and the effective dialogue between ART and the regulated actors, data-driven regulation is a realistic target over the next few years for the rail industry. In other sectors such as motorways and ports, this objective is much further away, since the availability of information is significantly lower. Therefore, it appears desirable to work on the progressive dissemination of a "culture of data" among stakeholders to enrich the databases currently available, which will make it possible to make regulatory choices in the future that will primarily benefit the market players themselves.

Disclaimer

The views and opinions expressed in this chapter are those of the author and do not necessarily reflect the official policy or position of the respective institution.

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3 Île-de-France

A natural but contested hinterland for Haropa port

Ronan Kerbiriou

Introduction

The term "Seine Axis" is widely used by planners, logistics professionals, politicians, and academics. It refers to an unusual context of relations among a major metropolis, the Greater Paris region, and a traffic corridor organized around the Seine River. Though this circulation route runs along a river, most of its traffic, leading to an international-scale port facility, is by road (Serry, 2018). The Seine Axis stands as a symbol for future maritime, logistics, and economic development and is a recurring theme in political discourse, as well as in collaborative projects between different institutional and private actors. The logistics and facilities of the ports of the Seine Axis serve the 12 million inhabitants residing in the Île-de-France region, a key generator of incoming and outgoing maritime flows. Haropa port, the merger of the three ports of Le Havre, Rouen, and Paris, is a natural transit point for goods coming from or going to the Île-de-France region. Yet, the current reality of traffic flows tells a different story. While certain maritime services in this area are provided by the Haropa centres, other ports in Northern Europe, such as the port of Antwerp, also play a major role in local operations. Given the lack of reliable and comprehensive data on the origins and destinations of goods transiting through these ports, it is difficult to establish the exact market share of each port in serving this area of France. It has been estimated, however, that more than 50% of the containerized goods transiting by sea to the Paris region are unloaded at the port of Antwerp, arguably making Antwerp the number-one port serving the Parisian population, as previous research has already pointed out (Charlier, 1990; Frémont & Franc, 2010; Guerrero et al., 2022). This therefore begs the question: Why is the Île-de-France region not better served by its own natural route, the Seine Axis? With the creation of the Haropa maritime complex, and by bringing together the various stakeholders along the Seine Axis, it is hoped that local facilities will be able to regain the market share eroded by its competitors.

The aim of this chapter is to shed light on the forces behind the fierce inter-port rivalries to serve the vast hinterland of the Île-de-France region. It will first examine the ways in which ports can compete to serve a hinterland, before delving into the specific rivalry between Haropa and Antwerp for the Île-de-France logistics area. Finally, this chapter will conclude by outlining the challenges of developing the multimodal transport that will enable Haropa port to re-stake its claim on the Paris Metropolis.

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The findings that form the basis of this chapter are drawn from research investigations undertaken within the framework of the DEVPORT research project. DEVPORT is a network of researchers interested in maritime transport, port organizations, and the territorial impacts of these activities. The project is based on the development of a Geographic Information System (GIS) originally dedicated to the Seine Axis. This GIS also incorporates Europe-wide data and a maritime interface that uses Automatic Identification System (AIS) signals from ships to study maritime traffic.

Hinterland and inter-port competition

The "hinterland" of a port refers to the land area that has an economic impact on its activities. This area is therefore the space within which a port provides its services and interacts with its customers (Rodrigue, 2020). The hinterland covers the point of origin and the place of destination of goods transiting through a given port. The area covered varies according to the economic activity of a port, as well as competition between different transport modes and the availability of intermodal forms of transport.

We can distinguish between two types of port hinterland: first, there is a "captive" hinterland, the area in the immediate vicinity of a port and which is therefore easily accessible. This port controls most of the traffic in the local area. Second, inland, there is a "competitive" hinterland, the competitiveness of which depends on the land links providing transport to and from the port. In this space, the port has to compete with other facilities for its trading activities (Rodrigue, 2020). The hinterland of a port also varies according to the product being transported.

Since the 1980s, due to the commercial strategies of shipowners and the need for greater economic returns, container ships operating providing intercontinental maritime services have been making fewer port calls and have tended to favour destinations offering a larger customer base. This trend has driven the growth of large European ports at the expense of certain smaller centres, as well as having a significant impact on the definition of port hinterlands. The hinterlands of large facilities such as the port of Rotterdam cover the whole of Europe, whereas the hinterlands of smaller ports struggle to extend beyond regional boundaries. We can therefore conclude that in general, and on a global scale, the concept of port hinterland has been undermined by the containerization of maritime transport (Slack, 1993). Within the Northern Range, however, this concept still proves relevant because of the geographical concentration of ports with important traffic, as Debrie and Guerrero point out (2008). In terms of transport geography, the authors also argue that the extension of a hinterland will depend on the quality of its communication routes, especially the multimodal connections allowing goods to be transported in a massified way and over longer distances, as is the case with road transport. Ports therefore strive to expand their hinterland with a view to increase their maritime traffic.

Goods transported in sea containers require processing prior to final delivery. These logistics operations are carried out in warehouses, facilities dedicated to storage, distribution, and repackaging activities. The main role of a warehouse is therefore to manage product stocks and prepare deliveries for shipment. Warehousing, by offering goods handling capacities, provides an important avenue for the logistics development of a geographical area, in addition to creating added value. Warehouses constitute land transit points for import and export goods passing through ports, and their location influences port passage choices. As a result, the proximity of warehouses to local ports plays a determining role in the maritime development of a given area (Kerbiriou, 2021). The proximity of warehousing sites and the dynamics of new infrastructure developments play a decisive role in a port performance of a given territory (Serry, 2019).

The next part of this chapter will analyse the inter-port competition in the Île-de-France region, with a particular focus on the ports of Haropa and Antwerp. It will examine the logistics organization and location of warehouses along the Seine Axis and more specifically in the Île-de-France region.

Île-de-France: a competitive hinterland

The symbolic weight of the Seine Axis stems from the economic and logistics growth potential it has to offer, especially in terms of serving the Île-de-France region. This region, boasting the fourth-largest economy in the world in terms of GDP, represents a substantial and valuable market to exploit. This zone accounts for about a quarter of all French exports and imports.[1] Haropa port seeks to position itself as the main seaport for the Paris region, leveraging its location as a natural maritime passage. For Haropa, the Île-de-France region constitutes an essential market area it will need to harness to develop its maritime traffic. However, the Île-de-France region is a "competitive" hinterland, with the fiercest competition being between the ports of Haropa and Antwerp. Without precise and standardized data on the origins and destinations of goods transiting through these seaports, it is difficult to ascertain precise market shares for each port facility. In terms of services to Île-de-France, it is often reported that 50% of the goods destined for this region are unloaded by the Flemish port. Though this figure cannot be considered reliable for want of statistical backing, it does provide some indication of the scale of the competition to supply this hinterland.

In view of the lack of standardized data on the origins and destinations of cargo flows transiting through ports, the use of a Huff model inspired by the spatial analysis of markets (gravity model) is an alternative solution, since reliable data on port access and traffic is freely accessible. For this purpose, the research forming the basis of this chapter was based on port statistics (container traffic in 20-foot equivalent unit [TEU] in 2021) and on the road distance travelled by trucks, while also accounting for road network constraints (average speed, restrictions, etc.). The weighting variables are thus the total container traffic of each port and the road distance, meaning that the probability of serving the region decreases with the square of the distance from the port. This decrease does not occur in a proportional way but rather with a power of two indicator. All major European port locations have been included in the construction of this theoretical hinterland calculation model. This model makes it possible to map out the geographical configuration of the road hinterlands studied and therefore of the services provided to the Île-de-France region (Figure 3.1). According to the model, the port of Antwerp has a 35% market share for services to the Île-de-France region, compared with 28% for Haropa port. The remaining market is shared by several ports including Rotterdam, Hamburg, and Dunkirk, among others. The results of this model show that the importance of Antwerp in serving the Île-de-France region is lower than the frequently cited figure of 50%. However, this does confirm claims of its position as the leading port serving this region, surpassing that of Haropa port. This model also confirms the competitive hinterland status of the Île-de-France region.

Next, this chapter will analyse the causes of Haropa's low market share for maritime services to the Paris metropolis, with a particular focus on the logistics organization of the Seine Axis.

The Seine Axis, structured around the Seine River, refers to the interface between its maritime gateway – symbolized by the port of Le Havre – and the Paris metropolitan area. The term "Seine Axis" is employed frequently in professional, political, and research meetings to highlight the assets this territory has to offer, as well as its importance for the logistics and economic development of France. However, this area is above all an industrial area inherited from *Les Trente Glorieuses*, a 30-year period of economic growth between 1945 and 1975, during which France saw the inception and organization of various structuring sectors, including the automotive sector. The strong presence of the automotive industry continues today, with the two leading French manufacturers, Renault and PSA, well established in the Seine Valley. These two manufacturers benefit from a good location, being surrounded by suppliers and equipment manufacturers (Faurecia, Bosch, etc.). The automotive industry in the Seine Valley accounts for 40% of French imports and 32% of its exports.[2] The pharmaceutical industry is another key sector that could be cited here: facilities located along the Seine Axis represent 40% of exports and 37% of French imports. Historically, then, the Seine Axis has been perceived as an industrial zone as opposed to a logistics area.

Though certain logistics activities are developed within the port of Le Havre, warehousing is a sector of activity that is mainly located in the Paris region. As mentioned earlier, the proximity of warehouses plays a determining role in the choice of port of passage. Between 1995 and 2020, nearly 17 million m² of warehouses larger than 2,000 m² were built along the Seine Axis, ten of which were in the Paris region. These developments could either be interpreted as a response to the functional logic of logistics chains near major facilities (terminals, freight airports, markets of national interests [MNIs], etc.) or to the logic of market access (Kerbiriou et al., 2019). In recent years, the prosperity of the Île-de-France region has been largely confined to the logistics zones located to the south, north, and east of Paris. Logistics has developed in this area to benefit from motorway links, such as the A104 motorway (la Francilienne), as well as competitively priced land (areas of agricultural origin). These warehouses are located on the opposite side of Paris from the ports of Le Havre and Rouen, making them more difficult to access (Figure 3.2). Land transport access to the major warehousing areas from the port

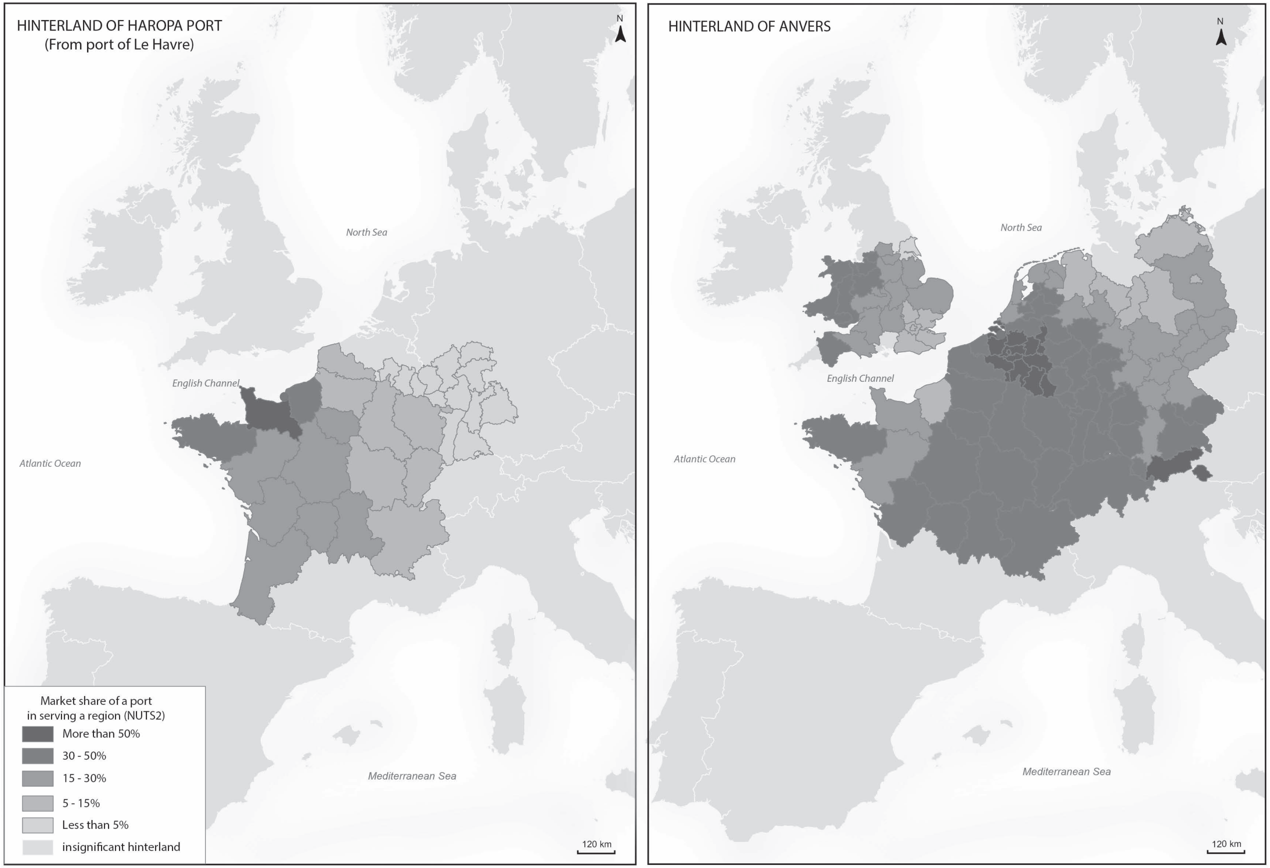

Figure 3.1 Modelling of the port hinterlands of Le Havre and Antwerp based on road transport.

Source: completed by author.

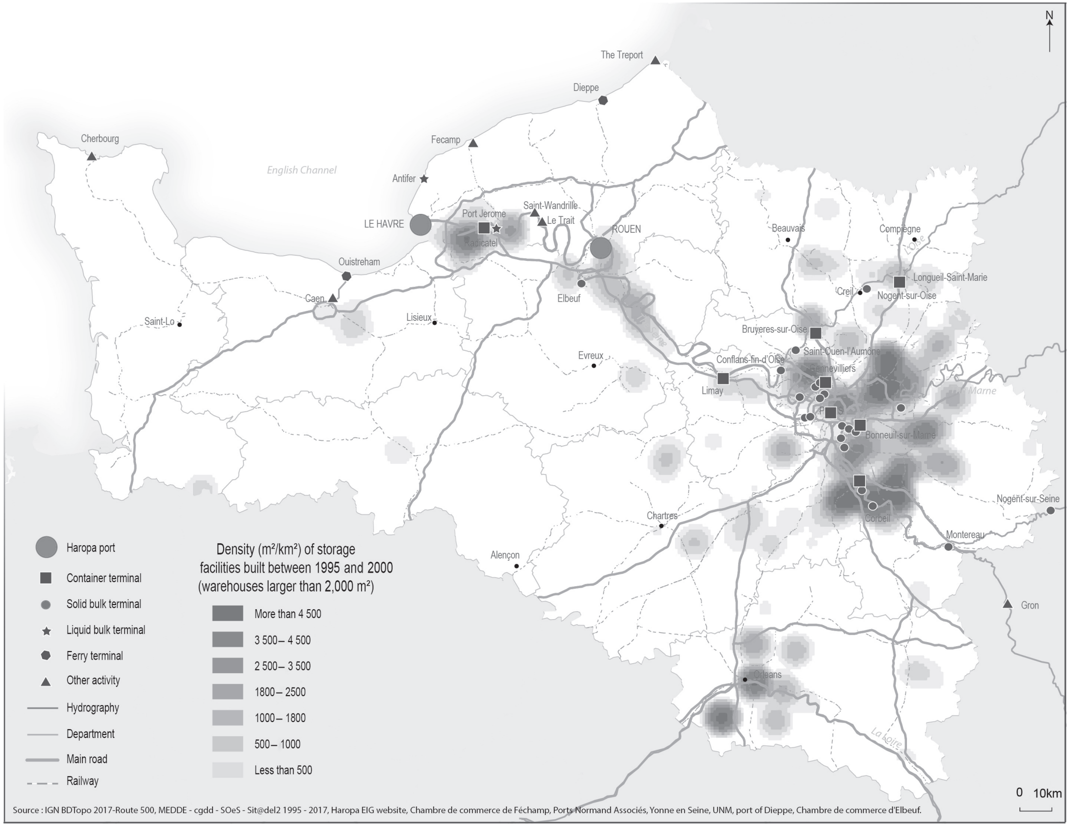

Figure 3.2 The Seine Axis logistics area.

Source: completed by author.

of Le Havre requires crossing the entire Paris region, which presents a number of challenges. For instance road transport has to contend with any possible traffic congestion. Road access to eastern Paris from the seaports of Le Havre and Rouen also requires travel through the Paris region, and so these traffic flows may be disrupted by difficult traffic conditions. As will be explained in the next section, freight companies are subject to a number of obstacles when it comes to using massified transport modes to serve these large logistics areas. Road transport is virtually the only mode of transportation used to serve these warehouse facilities. At the same time, this location facilitates road access from other northern European ports, especially the port of Antwerp. The vast majority of containerized goods imported from the port of Antwerp to the Paris region are transported by truck. The difference in shipping time is only one to two hours, which is insignificant given the maritime transit times and port passage times. The Île-de-France logistics market can therefore be considered as equidistant from Le Havre and Antwerp. From the port of Antwerp, by road, it takes four to five hours to reach the 15 million m^2 of warehouses built throughout eastern Paris since 1995, compared with just over three hours from the port of Le Havre.

The location of the main logistics areas on the other side of Paris is problematic in terms of maritime access to or from the ports of Normandy (Kerbiriou, 2021). Not all of these warehouses located in the Paris region serve the Parisian consumer market, but their areas of influence vary considerably. The bulk of Haropa port's container traffic goes to or comes from the regions of Upper Normandy and Île-de-France (Guerrero, 2010). The development of multimodal transport is an important driver for port and economic activity, as well as for environmental protection, as it allows for the massified evacuation of goods and the provision of services to hinterland areas further afield. In a modern maritime world where consolidation reigns supreme, the development of consolidated maritime transport is essential to enabling Haropa port to conquer market shares in serving the Île-de-France region. In 2021, 15% of the containers leaving the port of Le Havre were transported by multimodal transport, meaning that the remaining 85% was shipped by road. By way of comparison, in the ports of Rotterdam, Antwerp, and Hamburg, multimodal transport accounts for approximately 50% of container transport.

The future development of Haropa port's traffic hinges on the implementation of logistics improvements in Normandy by closing the distance between its warehousing and port facilities. This will offer a competitive advantage to the ports of Normandy, and in particular those of Le Havre and Rouen. To achieve this, port centres will have to address challenges related to the identification of available land, its oversight, as well as the development of storage facilities. Furthermore, in order to serve the major logistics zones found in the Île-de-France region, the expansion of multimodal transport services is essential, but these alternatives to road transport come with their own set of obstacles that port facilities will need to overcome (Kerbiriou & Serry, 2021). In the following section, the main reasons for the lack of multimodal transport between Le Havre and the Paris region will be examined, along with potential avenues for future improvement.

The development of multimodal transport: prospects and challenges

As mentioned earlier, the Île-de-France region is a competitive hinterland, but through the use of multimodal transport, Haropa port should be able to become more competitive and therefore attractive through the provision of massified land transport services.

Multimodal transport is used all along the Seine Axis, specifically to access the major logistics areas of Île-de-France identified earlier. These modes of transport also entail a fair share of constraints, which vary from one type of transport to another. Rail transport, for example, is faced with numerous infrastructure problems: difficulties bypassing the centre of Paris, failure to connect logistics areas to the rail network, prioritization of passenger transport, ageing infrastructure in need of maintenance work, major investments in high-speed lines at the expense of capillary networks, and so on. This observation also holds true for services to other important French territories (such as the areas surrounding Lyon, Strasbourg, and Bordeaux) or to Europe, which almost systematically require an intermodal transfer at Valenton, situated south of Paris. These infrastructural problems hamper the competitiveness of rail freight transport from Haropa's ports. The modal share of rail transport has eroded to almost marginal levels. A number of projects are underway to facilitate the revival of rail transport, such as the creation of the multimodal terminal in Le Havre or the electrification of the Serqueux–Gisors segment, which should provide additional railway paths for the transport of goods. Even so, one of the most crucial challenges will be restoring stakeholder confidence in combined modes of transport, which has long been abandoned in favour of road-only freight services.

The use of river transport will inevitably be subject to limitations due to bridge heights, limiting the number of containers to two rows instead of four at the port of Gennevilliers. The Gennevilliers terminal handles more than 80% of the container traffic in the Île-de-France region. In fact, most river container transport transits through the port of Gennevilliers, with a minority share passing through Bonneuil-sur-Marne. Long pre- and post-transits in dense urban areas are necessary to serve the large logistics areas identified above from the Gennevilliers terminal. The port of Bonneuil-sur-Marne is better located, but its service is limited by the need to cross Paris and by bridge heights, resulting in a costly reorganization of downstream convoys at Gennevilliers (Frémont, 2012). As far as river transport is concerned, the problem lies not in the river mode itself, but in the pre- and post-haulage by road, which impacts heavily on transport and handling costs (Figure 3.3).

In the wake of policies aimed at rationalizing transport and bringing down costs (and therefore shipping prices), road transport has outstripped the use of combined transport. Container road hauliers offer their customers various transport schemes, such as the "round trip" service, that is, an outward journey with a full container and a return of the empty container to a maritime depot (Frémont & Franc, 2010). Combined transport is not in a position to offer an equivalent container restitution solution, and containers will instead need to pass through an inland depot, the main ones being located at the Gennevilliers terminal. On the map in Figure 3.3,

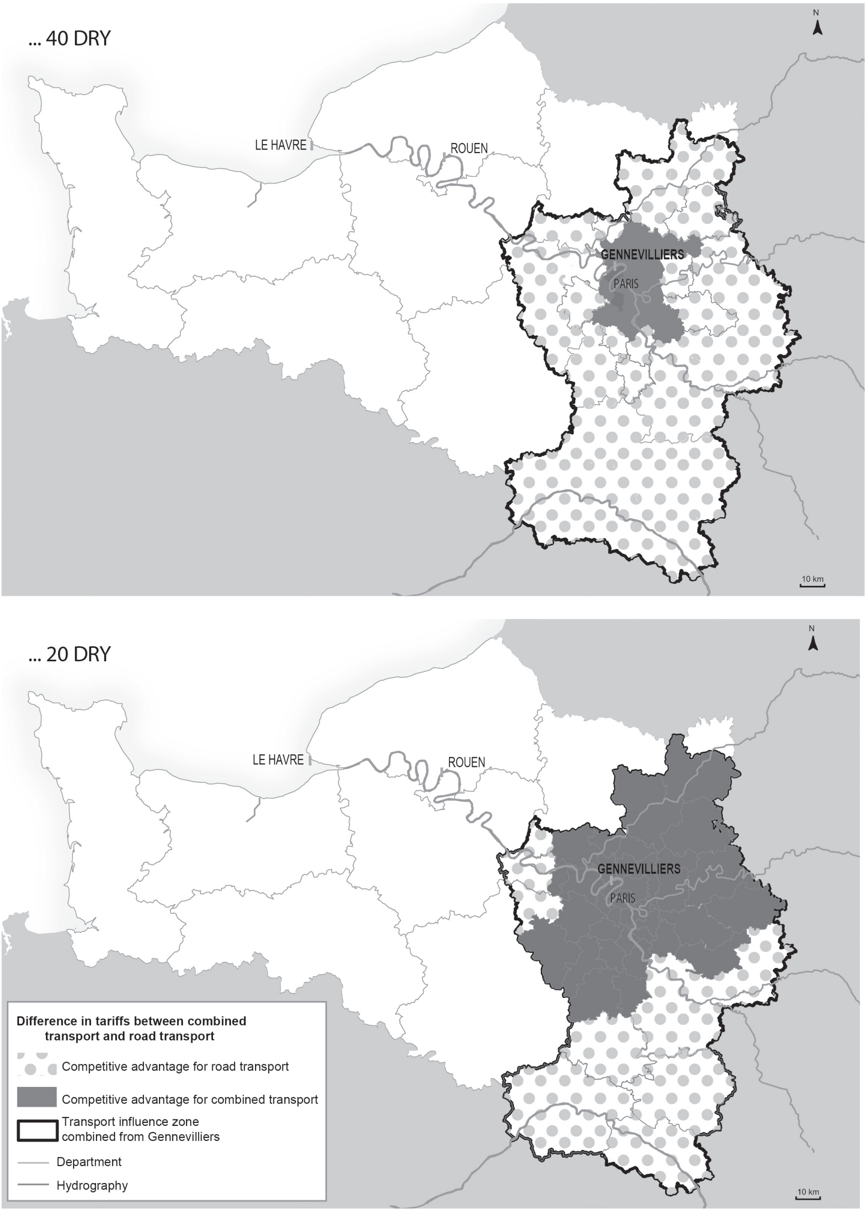

Figure 3.3 Cost difference between combined transport and road transport from the port of Gennevilliers for the import of a container.

Source: author.

a comparison is made between the import costs between river transport and road transport for a 20 ft container and a 40 ft container for a one-way trip (return of the empty container to an inland depot). These tariffs were provided by land transport operators working between Le Havre and the Paris region, either as carrier haulage or merchant haulage. However, for reasons of commercial confidentiality, the names of the companies involved cannot be disclosed here. These transport operators use the "dico-route" division – the breakdown of the department into several zones – and apply a tariff per zone. In this way, it was possible to obtain the tariff schedules for all-road transport and multimodal river-road transport for the dico-route zones of the Paris region from Le Havre. This has, in turn, allowed for the creation of a price comparison between the different modes of transport studied with a view to categorize the zones presenting a competitive cost advantage in favour of road transport and those in favour of multimodal transport.

Generally speaking, river transport does prove competitive for the import of a 20 ft container, but not competitive for that of a 40 ft container, despite the latter being in higher demand. The main logistics parks in the Paris region are located in areas where road transport offers a competitive advantage. The challenge with multimodal river-road transport therefore arises during the post-road transport stage. In congested and densely populated regions, this form of transportation has a significant impact on the cost of multimodal transportation. This geographical distance offers an advantage to all-road transportation. The port of Gennevilliers has the potential to become a major gateway for goods entering the Île-de-France market, but river transport is often deemed too complicated and unreliable and will have to become more competitive in terms of transport costs to be considered a viable transport solution.

To restore an additional margin, inland waterway transport operators are calling for the abolition of THCs (Terminal Handling Charges). These handling costs are charged to inland shipping companies, whereas the loading of wagons or trucks is already included in terminal fees. In other European ports, inland waterway transport operators do not pay THCs, which are instead covered by maritime transport. Since 2016, THCs are no longer charged at the port of Dunkirk, which has paved the way for the development of local inland waterway transport. And more recently, since April 2022, the THCs for river transport at the ports of Le Havre and Marseille have been covered by CMA-CGM, a shift which appears to be yielding direct results – these facilities have seen a 30% increase in the number of containers loaded on the Seine (source: news broadcast from 7 December 2022).

Conclusion

The Île-de-France region is at the heart of France's foreign trade, with many goods destined for this consumer market or for export further afield passing through its roads and waters. However, its maritime services are subject to stiff competition from other European ports, particularly due to the location of logistics spaces in the east of the Île-de-France region. Since the turn of the century, we have seen the implementation of large-scale national projects, often at State level, to foster the logistics and inter-port development of the Seine Axis (the high-speed rail project linking Paris to Normandy, Haropa port's strategic plans, the Grand-Paris urban development project, Seine Visions 2040, etc.). Through the development of multimodal transport, Haropa port will be able to regain market share in its natural hinterland. To this end, these port facilities will need to develop reliable river or rail services in close proximity to local logistics zones in order to limit the need for pre- and post-carriage by road. The development of multimodal transport will equally make it possible for ports along the Seine Axis to expand its hinterland and thereby ensure the massified evacuation of goods from maritime terminals. This will, in turn, increase maritime traffic and help address the major environmental challenges facing the world today. Several projects are already under way or in preparation, such as the river connection of the Port 2000 container terminals or the electrification of the Serqueux–Gisors railway line. Still, the main constraints are felt in the Paris region and are yet to be resolved. For instance since river barges cannot cross Paris at full load, in the vast majority of cases they will unload their containers in the port of Gennevilliers. Hence, it seems that the distance covered for river transport serving the major logistics areas of the Île-de-France region will never reach a fully optimal level. The main issue therefore boils down to transport cost, and lower costs are needed to make river transport more competitive.

While, in theory, rail transport makes it possible to serve logistics areas in a massified manner, in reality, it has to contend with a number of infrastructure problems (in contrast to river transport, since the Seine is navigable on a large gauge without tidal constraints). The challenge here lies in effectively transporting goods in close proximity to logistics zones, which will require considerable investments in the rail network or freight stations near warehouses. By enhancing its rail network, Haropa port should be able to extend its hinterland and become more competitive.

Another important issue is the development of logistics spaces in Normandy – that is, the organization of facilities as close as possible to the port passage, thereby offering the ports of Normandy an edge over rival centres. For this to be possible, the identification and inspection of available land will be crucial (Kerbiriou, 2021).

As the opening of the Seine Nord Canal draws near, the port community as a whole has pledged to address these key issues, to stay the course of the port and logistics development in the Seine Valley and to enable Haropa to hold its own as a leading world port.

Notes

1 Chiffres du commerce extérieur français (French external trade statistics), Département des Statistiques et Études du Commerce Extérieur (DSECE) (External Trade Statistics and Analyses Division) of the Direction Générale des Douanes et des Droits Indirects (DGDDI) (Directorate-General of Customs and Indirect Taxes). https://lekiosque.finances.gouv.fr/

2 Datadouane (2020). *DGDDI*. www.douane.gouv.fr/la-douane/opendata

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4 Intermodal transport versus road transport

The benefits of a cost-based analysis of activities in the Seine corridor

Patrick Niérat and Sacha Rybaltchenko

Introduction

Intermodal transport refers to the movement of goods from one point to another using several modes of transportation. In this study, we focus on the most common mode, namely long-distance rail and barge freight, to which pre- and post-haulage by truck can be added to cover the first and last kilometres, respectively. This intermodality allows massified modes of transportation such as rail and waterways to compete with long-distance road freight. Indeed, intermodal transport offers far more flexibility, especially from a spatial point of view: The shipper and the recipient no longer need to have their own terminal; they only need to load and unload trucks.

With the aim of developing intermodal transport in the Seine corridor, the Le Havre multimodal terminal was launched back in 2015. This port complex is connected to the port of Le Havre and Greater Paris by rail and inland waterways (River Seine). For a shift from road freight to intermodal freight to be possible, keeping costs down is crucial, as economic viability is one of the biggest incentives for such a modal shift. Having the ability to calculate intermodal costs will therefore allow researchers and local actors to gauge the possibility of a future modal shift and to analyse the current level of traffic in Le Havre multimodal terminal.

However, carrying out such calculations is far from simple – various problems arise when attempting to model freight transport. For example, given the limited amount of data offering a sufficient level of spatial disaggregation, data reconstruction is necessary when assessing the impact of transport policies. Three literature reviews proposed by De Jong et al. (2004, 2013, 2021) analyse European models and the progress made over time. Though many operational improvements have been made (introduction of logistics, integration of interurban and urban dimensions, etc.), data is still lacking, and the process of distributing these data across and within regions has yet to see much improvement.

Over the course of this chapter, we will address three issues encountered in the analysis of intermodal transport: First, the evaluation of potential flows; second, the comprehensive calculation of costs, that is effectively factoring in every stage of the journey, especially the first and the last kilometres; and third, the comparison

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of the total annual cost of different solutions. To keep our analysis from being overly general, we draw on a number of recent studies to illustrate the difficulties faced and to show how assumptions have a profound impact on outcomes.

As a reference for our analysis, we refer to Hintjens et al.'s 2020 study, which proposes formulas for calculating road and intermodal costs of seaports. In this chapter, the authors put forward a multicriteria approach: in addition to the direct costs paid by customers, they also factor in value of time and external costs (such as environmental impact). By adopting this approach ourselves, we can generate a "full cost," or we can instead consider each criterion separately. The main disadvantage of these formulas, however, is that pre- and post-haulage are not taken into account. The researchers based their analyses on the assumption that all regional traffic originates from a single maritime port, when in reality it comes from all across the region, and goods need to be carried from their regional origin to the destination port.

The issues present in Hintjens et al.'s research (2020) do not represent an isolated case. Janic (2007), for instance, compares the total direct and full (direct and external) costs of a road and intermodal transport network. In this comparison, Janic fails to account for the dispersion of origins and destinations, all of which are located within 50 km of the terminals. Janic's research shows that when external costs are integrated, longer distances must be travelled for intermodal transport to be profitable if traffic volume is not high enough. Santos et al. (2015), on the other hand, study the impact of several Belgian policies on intermodal competitiveness by minimizing the total cost of transport. Faced with data gaps, they allocate regional traffic to regional subsets in proportion to the number of companies in the productive sector. They argue that subsidies play a critical role in the success of intermodal transport and that the internalization of external costs may have an adverse effect on logistics activities in certain cases because of road pre- and post-haulage. Hu et al. (2019) provide a review of the literature on inter-terminal transport planning where research aims at maximizing transport volume while reducing cost. The authors identify a number of shortcomings, including the need to develop quantitative methods to analyse the financial interest of different actors. Other works, by contrast, do not quantify flows but focus on the changes brought about by transport policy according to location. Meers et al. (2018) conducted a study that identifies the Belgian municipalities that would experience a decrease in direct transportation expenses for their trade with the port of Antwerp if they replaced intermodal solutions with three TEU (20-foot equivalent unit)-capacity LHVs (longer and heavier vehicles) instead of the current use of two-TEU capacity HGVs (heavy goods vehicles). In the field of port competition, Wang et al. (2016) define the hinterland of ports based on a probabilistic model that combines shippers' geographical information with analysis of their route choices. Like the latter two works, our study does not provide a quantitative solution for the modelling itself. It does, however, demonstrate the consequences of the assumptions made around intermodal transport, which are likely to shape the hierarchy of solutions. Our study also presents possible approaches that could address the difficulties encountered.

Case study

The main goal of this study is to calculate and compare the costs of intermodal and road transport solutions along the Seine corridor. With 12 million inhabitants and 30% of France's gross domestic product, the Paris region is located at about 200 km from the port of Le Havre. This corridor benefits from efficient infrastructures for waterway transport (the River Seine is navigable up to the river port of Gennevilliers for large ships carrying two hundred and fifty 20 ft containers); road transport with the A1 motorway; and rail transport, with rail lines allowing for the circulation of eighty 20 ft container trains.

When carrying goods across the Seine corridor from the Le Havre region to the Paris region (Île-de-France), shippers have the choice between using truck-only freight from origin to destination, which we refer to as a "long-distance road solution," and opting for intermodal alternatives. Le Havre has a trimodal terminal which forms part of the seaport. This terminal is connected to road, rail, and inland waterways (IWW). In the Paris region, on the other hand, there are three rail terminals: Noisy-le-Sec, Valenton, and Bonneuil-sur-Marne. Since the latter is very close to Valenton, we have decided not to include it in our study. Finally, there are two IWW ports in Gennevilliers and Bonneuil-sur-Marne. We therefore have two intermodal solutions for carrying freight from the Le Havre region to the Paris region (Figure 4.1):

- rail-road: freight is transported from its origin to the Le Havre terminal by truck, then transshipped onto a train going to either the Noisy-le-Sec or Valenton terminal. It is then transshipped again onto a truck which goes to the final destination.

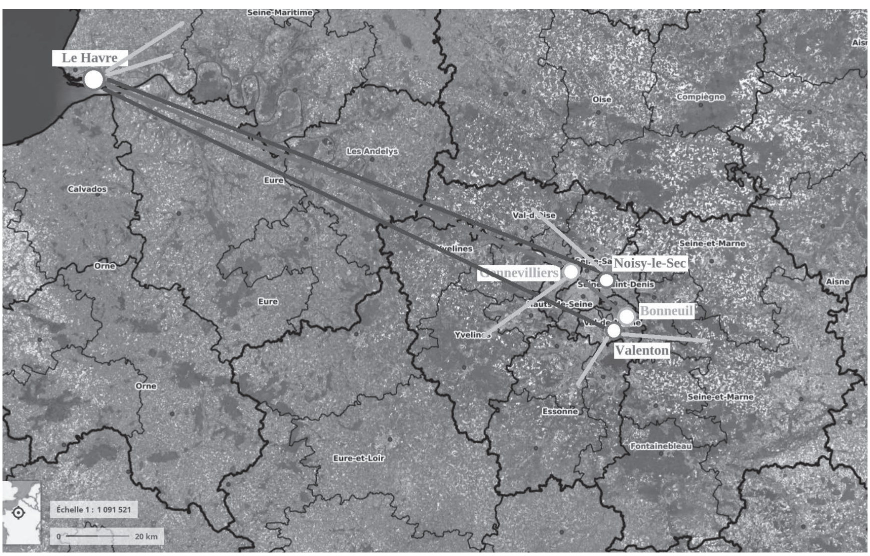


Figure 4.1 Intermodal solutions: light grey represents road, dark grey represents rail, and black represents waterways (IWW).

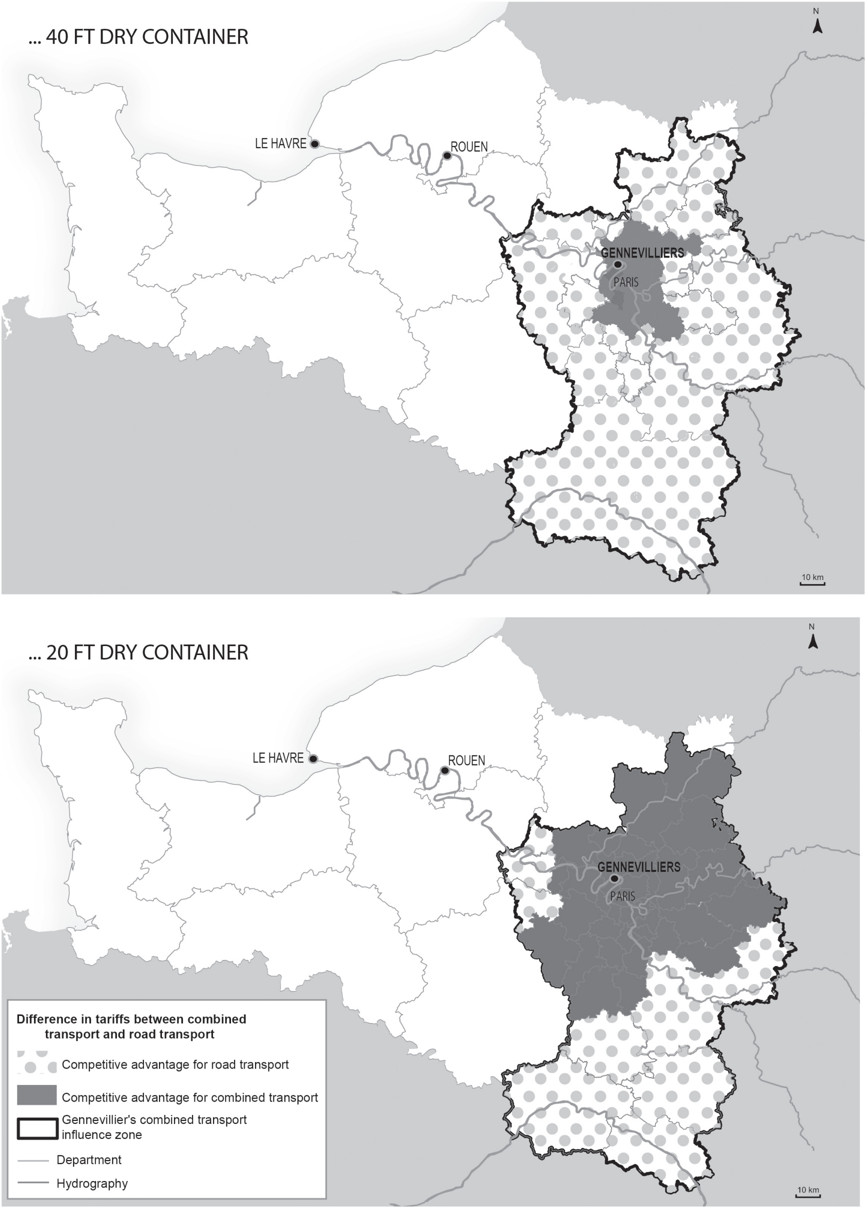


Figure 4.1 (Continued)

- IWW-road: freight is transported from its origin to Le Havre terminal by truck, then transshipped onto a barge going to either the port of Gennevilliers or the port of Bonneuil. It is then transshipped again onto a truck which goes to the final destination.

As we are interested in a potential modal shift from long-distance road transport to intermodal solutions, in this study we calculated the transport costs of existing road traffic between the Le Havre region and the Paris region, for each of our three transport solutions. By comparing costs, we assessed the competitivity of each solution, in line with a set of variable parameters.

Data and method

To effectively calculate the costs of these intermodal transport solutions, we needed to factor in the volumes transported as well as the distances between origins and destinations. In terms of volumes, we used the mean daily truck traffic from the Seine-Maritime department to each of the departments in the Île-de-France region (Roger, 2018). Our focus was on road flows, as we are interested in potential modal shifts from road to intermodal transport. These data were compared to the Road Freight Transport (RFT) survey (Ministère de la transition écologique et de la cohésion des territoires, 2018). We carried out our analysis based on the assumption that trucks were loaded to an average of 9.8 tonnes and operated for 200 working days per year. Though the selected data are relatively reliable, they do not provide sufficient information about truck loads: we had to draw our own assumptions about the number of TEUs transported and the associated tonnages. For rail distances, we used diagrams provided by the major French railway company, the SNCF (Wikipedia, 2022), for the main sections. For the smallest sections, especially in the Île-de-France region, we measured the distances on Géoportail (2022), a comprehensive web-mapping service provided by the French government. The river distances were obtained using the web tool provided by Voies navigables de France (2022). Finally, we calculated the road distances on viamichelin.fr, a digital travel assistance service provider owned by the Michelin Group, making sure that the proposed route was accessible to trucks, that is composed of motorways or *routes nationales* (a class of trunk road in France). The data on volumes transported are on a departmental basis. To calculate road distances, each department was represented by a centroid. These centroids were chosen arbitrarily: cities considered to be at the centre of the economic activity of their department were selected for this purpose. Post-haulage distance represents the distance between the arrival terminal and the centroid of the destination department. Centroids are shown in Table 4.1.

Our calculations were based on the method formulated by Hintjens et al. (2020), which is the result of a meta-analysis. This method consists of a multicriteria approach to calculate three costs: direct costs, that is those actually paid; cost of time, obtained from a value of time (VoT); and external costs, assigning a price to externalities such as greenhouse gas emissions. We refer to the sum of these three components as “full cost.”

In our calculation, we corrected an important omission in Hintjens et al.’s approach with respect to the intermodal solution, namely the omission of pre- and post-haulage to and from terminals. We therefore included the additional costs of these short-distance trips, which are an integral part of the intermodal transport

Table 4.1 Chosen centroid for each department.

Department	*Department number*	*Centroid*
Paris	75	Paris
Seine-et-Marne	77	Tournan-en-Brie
Yvelines	78	Saint-Quentin-en-Yvelines
Essonne	91	Montlhéry
Hauts-de-Seine	92	Nanterre
Seine-Saint-Denis	93	Aulnay-sous-Bois
Val-de-Marne	94	Créteil
Val d'Oise	95	Auvers-sur-Oise

concept itself. We then applied this corrected method to the case of the ports of Dunkirk and Zeebrugge included in Niérat's recent analysis (2022). That said, a specificity of the Le Havre terminal is that it receives freight "from the port," that is transported by sea in container ships for example. In this particular case, then, there is no pre-haulage as such, because, on the one hand, the origin is the port and therefore the same for all transport alternatives, and on the other hand, we assume that transshipment in the Le Havre terminal is invoiced at the same price (Terminal Handling Charges) for trucks, trains, and barges (Berrier, 2022). However, in order to evaluate the traffic flows coming from around the areas surrounding the port that could be incorporated to have greater volumes between Le Havre and Paris, we also introduced the proportion of goods coming from the port of Le Havre as a parameter in our study.

Formulas providing costs are the following:

$$Direct\,cost_{road} = c_d^{rail}\left\lfloor \frac{Volume}{Capacity_{truck}} \right\rfloor Distance + c_t^{road}\left\lfloor \frac{Volume}{Capacity_{truck}} \right\rfloor \left(t_{driving} + t_{waiting} + t_{resting}\right)$$

$$Direct\,cost_{rail\ or\ IWW} = c_d^{rail\ or\ IWW}\left\lfloor \frac{Volume}{Capacity_{train\ or\ barge}} \right\rfloor Distance + c_t^{rail\ or\ IWW}\left\lfloor \frac{Volume}{Capacity_{train\ or\ barge}} \right\rfloor \left(t_{driving} + t_{waiting} + t_{resting}\right)$$

$$Direct\ cost_{intermodal} = Direct\ cost_{rail\ or\ IWW} + \underbrace{Direct\ cost_{road}}_{pre\ and\ post\ haulage} + 2c_{transshipment} Volume$$

$$VoT\ cost_{road} = VoT \times Volume \times \left(t_{driving} + t_{waiting} + t_{resting}\right)$$

$$VoT\ cost_{rail\ or\ IWW} = VoT \times Volume \times \left(t_{driving} + t_{waiting} + t_{handling}\right)$$

$$VoT\ cost_{intermodal} = VoT\ cost_{rail\ or\ IWW} + \underbrace{VoT\ cost_{road}}_{pre\ and\ post\ haulage}$$

$$External\ cost_{road} = c_{ext}^{road} \left\lceil \frac{Volume}{Capacity_{truck}} \right\rceil Distance$$

$$External\ cost_{rail\ or\ IWW} = c_{ext}^{rail\ or\ IWW} \left\lceil \frac{Volume}{Capacity_{train\ or\ barge}} \right\rceil Distance$$

$$External\ cost_{intermodal} = External\ cost_{rail\ or\ IWW} + \underbrace{External\ cost_{road}}_{pre\ and\ post\ haulage}$$

Where c_d is cost per km (€/km), c_t is cost per hour (€/h), $C_{transshipment}$ is transshipment cost (€/TEU), VoT is unit value of time (€/h) and C_{ext} unit external costs (€/veh/km). The values for these parameters are taken from Hintjens et al. and are shown in Table 4.2. The cost components are given for 2018 and are based on a literature review conducted by Hintjens et al. (2020).[1]

Table 4.2 Values of fixed parameters.

Parameter	*Unit*	*Road*	*Rail*	*IWW*
Direct costs per km (c_d)	€/km	0.6	6	8.6
Direct costs per hour (c_t)	€/h	43	265	265
Unit value of time (*VoT*)	€/h/TEU	1.13	-	-
Unit external costs (c_{ext})	€/veh/km	0.62	2.73	10.52
Average speed	km/h	65	55	10
Waiting time ($t_{waiting}$)	h	1.5	1	7
Resting time ($t_{resting}$)	h	1	0	0
Handling time ($t_{handling}$)	h	0	20	3
Vehicle capacity (*capacity*)	TEU/veh	2	64	180
Tonne per TEU	t/TEU	10	-	-
Transshipment cost ($c_{transshipment}$)	€/TEU	50	-	-

Source: Hintjens et al. (2020).

We calculated the cost of transporting the annual volume currently carried by road from the Seine-Maritime department to the departments of Île-de-France. These costs were obtained for long-distance road transport, that is, by truck from end to end and for intermodal rail–road and river–road solutions. For each origin–destination pair, an arrival terminal had to be chosen for the intermodal solutions, and the terminal that minimizes full cost was selected. The costs calculated using this approach were plotted per TEU for better readability.

Results: the role of spatial distribution

In this section, we will outline the costs of transporting the annual volumes currently carried by road from the Seine-Maritime department to all our centroids in the departments of Île-de-France. In our calculations, we found that intermodal solutions offered the lowest external costs in all cases, in keeping with the environmental objectives implicit in the intermodal transport model. In terms of other costs, however, the situation was quite different.

Three parameters were studied:

1. Pre-haulage distance, that is mean distance between the point of origin and the Le Havre terminal;
2. The proportion of goods coming from the Port of Le Havre compared to regional traffic coming from the surrounding area; and
3. Truck loading (one or two TEUs per truck), for long distances as well as for pre- and post-haulage.

The first and second parameters represent spatial distribution of origins. The third parameter affects road efficiency: the cost per TEU for road transport with a one-TEU load is approximately double that of a two-TEU load. This is because in the latter situation, only one truck and one driver are needed to carry two-TEU load, whereas in the former situation, two trucks and two drivers are required. In practice, truck loading is affected by two factors: weight and transport scheduling. In France, a truck can carry two TEUs but may carry just one TEU if it is very heavy and reaches maximum loading weight, or if transport scheduling involves some trucks not being fully loaded.

Two TEUs per truck

With two TEUs per truck, long-distance road freight consistently offers the lowest costs, for any mean pre-haulage distance, with no traffic coming from the port (Figure 4.2) and for any traffic share coming from the port with a mean pre-hauling distance of 50 km (Figure 4.3). Thus, shifting all traffic to intermodal modes would not be a cost-effective solution. However, as we will show later, intermodal alternatives may prove to be more economically viable than road transport in specific

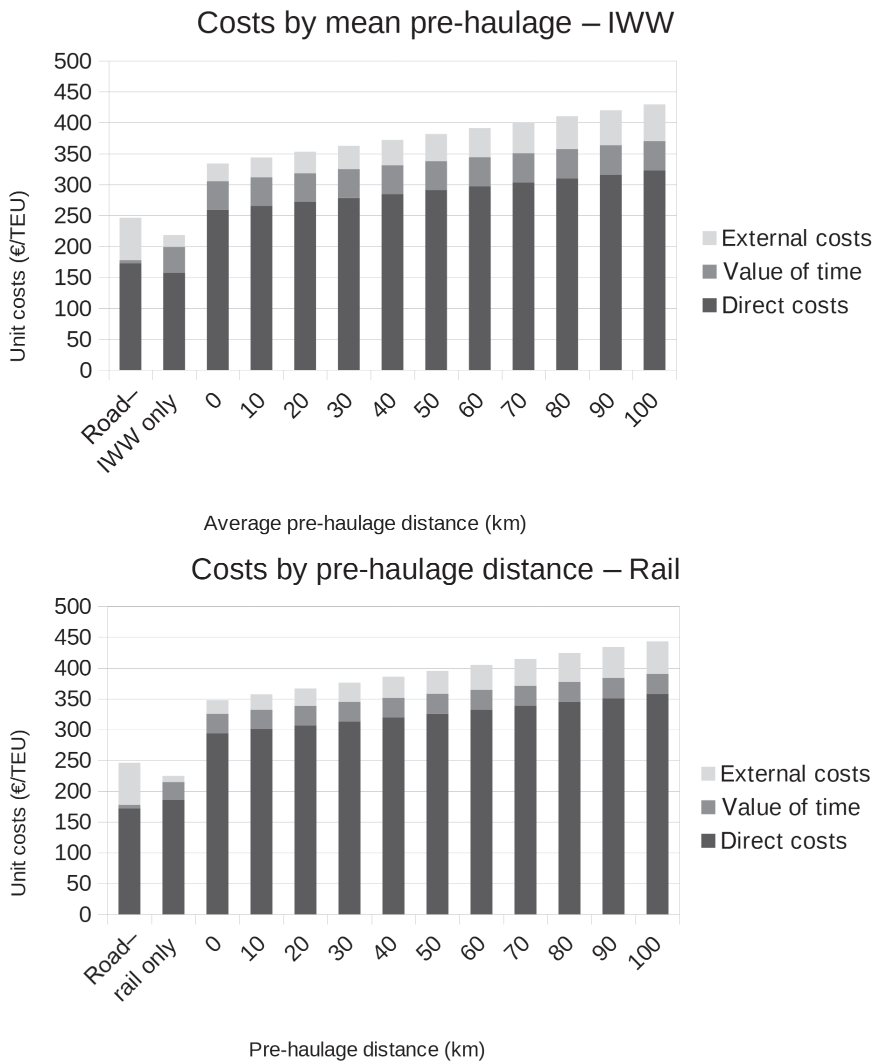


Figure 4.2 Two TEUs per truck: costs per TEU of IWW–road transport (a) and rail–road transport (b) against mean pre-haulage distance, assuming there is no traffic coming from the port. Long-distance road costs and intermodal costs calculated without pre- and post-haulage are plotted on the left of each diagram.

areas of the Île-de-France region. A key point revealed by our research is that if we omit pre- and post-haulage, we find that intermodal solutions offer the lowest full costs and even lowest direct costs for the IWW–road solution. These findings are a testament to the impact of the first and last kilometres in intermodal freight, especially for short hauls such as Le Havre–Paris.

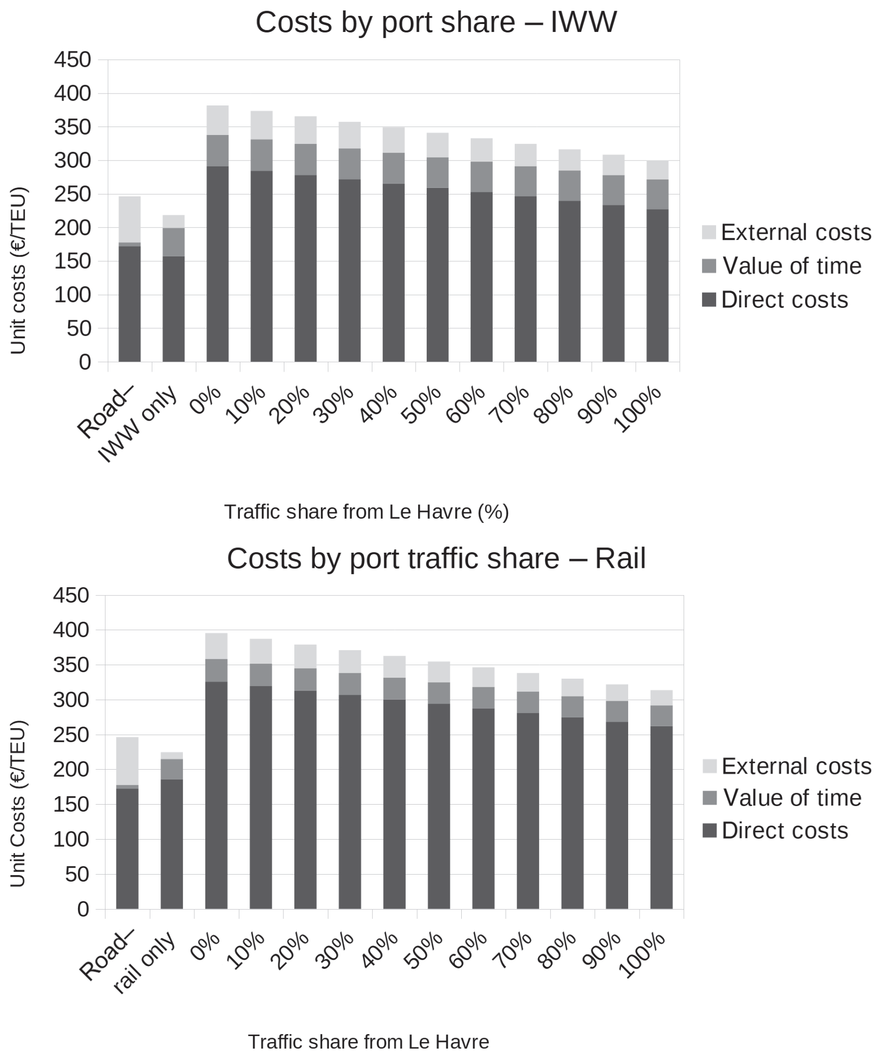


Figure 4.3 Two TEUs per truck: costs per TEU of IWW–road transport (a) and rail–road transport (b) against traffic share coming from the port, assuming a mean pre-haulage of 50 km for regional traffic.

In addition, our calculations revealed that IWW–road transport involves lower costs than rail–road solutions. There are several reasons for this: first, IWW has lower costs per TEU than rail transport. Second, IWW ports and rail terminals have different locations, so the post-haulage distances vary, and there is a preference for IWW–road over rail–road transport since there is a large traffic share in the Yvelines department, which is closer to the Gennevilliers Inland Port than rail terminals. This could offer an explanation as to why river transport is a transport mode of choice along this corridor today.

One TEU per truck

With one TEU per truck, road transport is less efficient, giving intermodal solutions the chance to shine. Indeed, we find that our parameters yielded some values that make intermodal freight competitive, even in terms of direct costs (Figures 4.4 and 4.5).

Nonetheless, our calculations also revealed that decreasing truck load from two TEUs per truck to one TEU per truck generates a significant increase in intermodal costs since, of course, intermodal solutions include road trips as well.

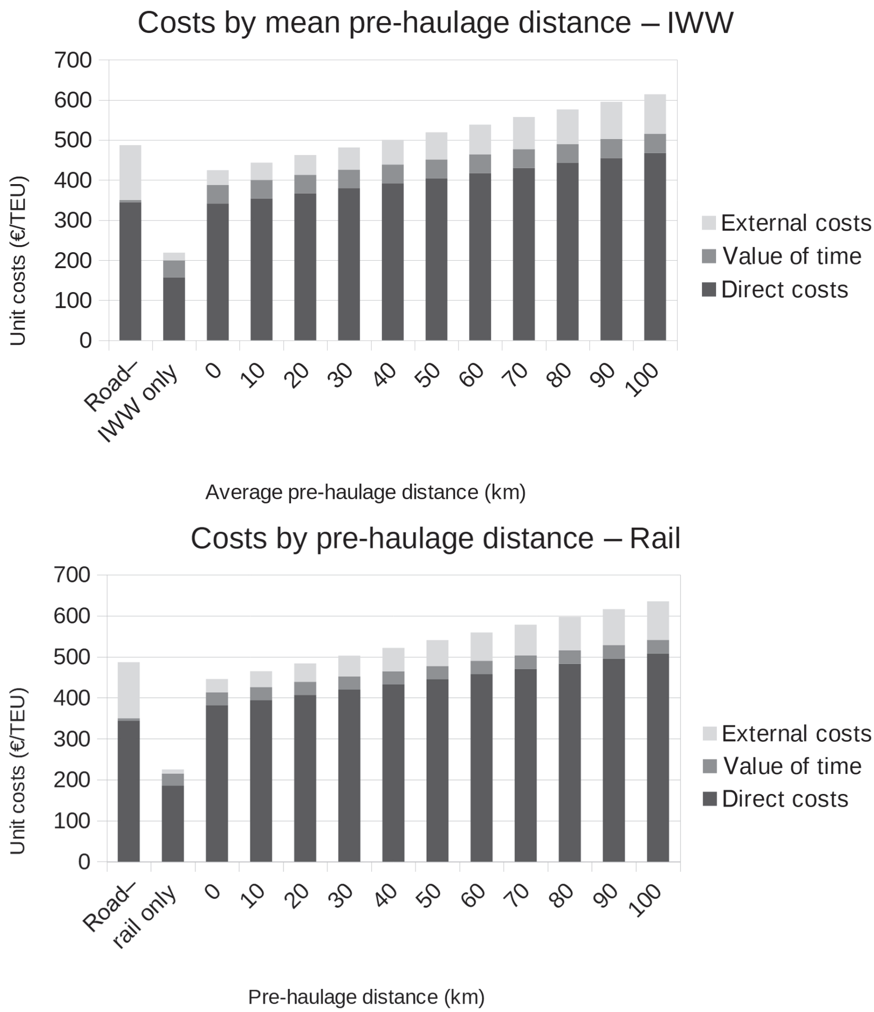
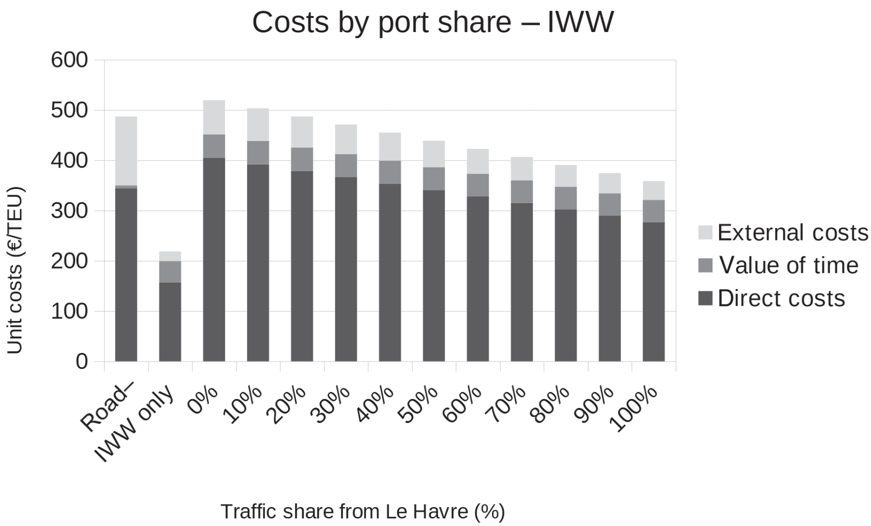


Figure 4.4 One TEU per truck: costs per TEU of IWW–road transport (a) and rail–road transport (b) against mean pre-haulage distance, assuming there is no traffic coming from the port.



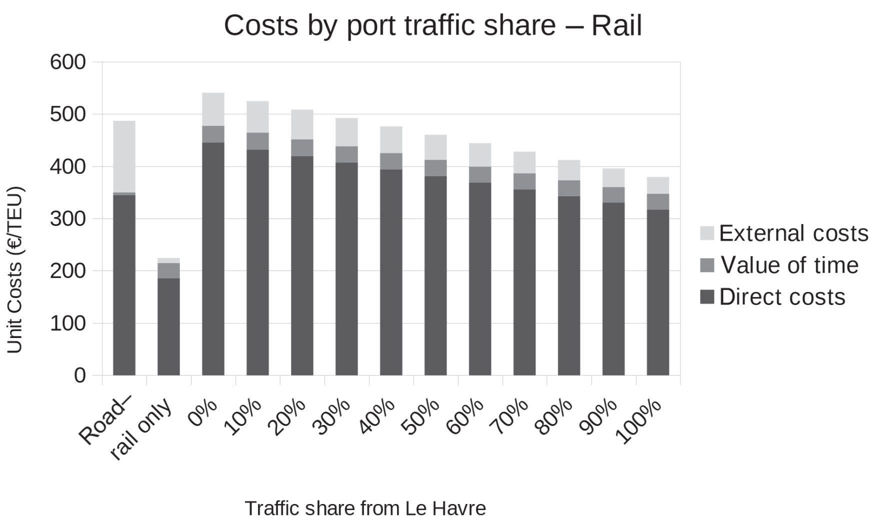


Figure 4.5 One TEU per truck: costs per TEU of IWW-road transport (a) and rail-road transport (b) against traffic share coming from the port, assuming a mean pre-haulage of 50 km for regional traffic.

Considering that with a truckload of one TEU, there are certain values of our parameters for which intermodal solutions offer lower costs than long-distance road transport, we find that for each value of the port's traffic share, there is a threshold value of the mean pre-haulage distance of regional traffic, below which intermodal solutions incur lower costs than long-distance road transport. This threshold value corresponds to equal costs between intermodal solutions and long-distance road alternatives. Using the full-cost approach mentioned

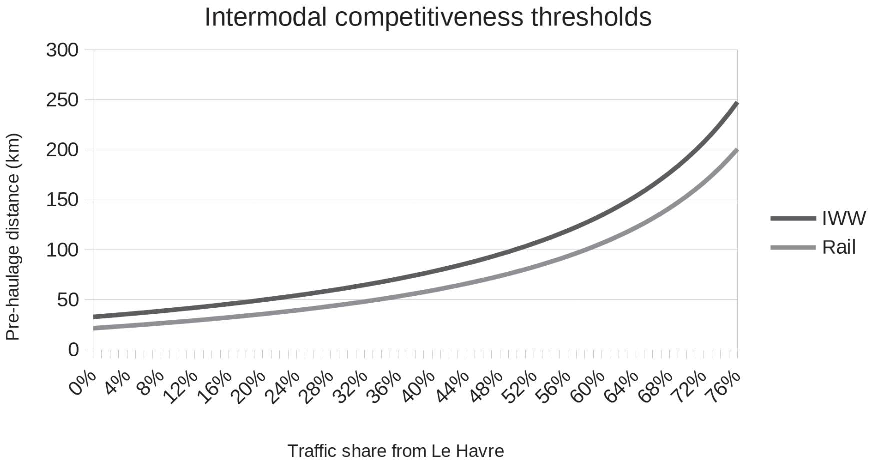


Figure 4.6 One TEU per truck: competitiveness areas of IWW–road and rail–road solutions. The former is under the black curve, the latter under the grey curve.

earlier, we plotted these threshold values against traffic share from the port in Figure 4.6. The competitiveness area of an intermodal solution lies below its curve.

Truck load had a considerable influence on the results: carrying a 40 ft container versus a 20 ft container had a major impact.

Costs for each department

So far, we have shown aggregated expenses, adding up the costs of all destinations. It is also worth examining the costs at a department level within the Paris region. In Figures 4.7a and b, we show the relative difference between intermodal and long-distance road solutions given by the formula $(Cost_{intermodal} - Cost_{road})/Cost_{road}$. We worked off the assumption that each truck carried a load of two TEUs per truck, and that all traffic comes from the port of Le Havre. We can see that intermodal solutions are highly penalized in western departments, such as the department of Yvelines (78). Conversely, departments close to terminals show little difference between intermodal costs and long-distance road costs, with a relative difference of less than 10% in the Val-de-Marne department (94), for example, which is close to the terminals of Valenton and Bonneuil. This further demonstrates the importance of spatial distribution: proximity to intermodal terminals has a significant impact.

Discussion

Our results show that, on the whole, intermodal transport (rail–road as well as river–road) is more expensive than all-road alternatives. This does not exclude

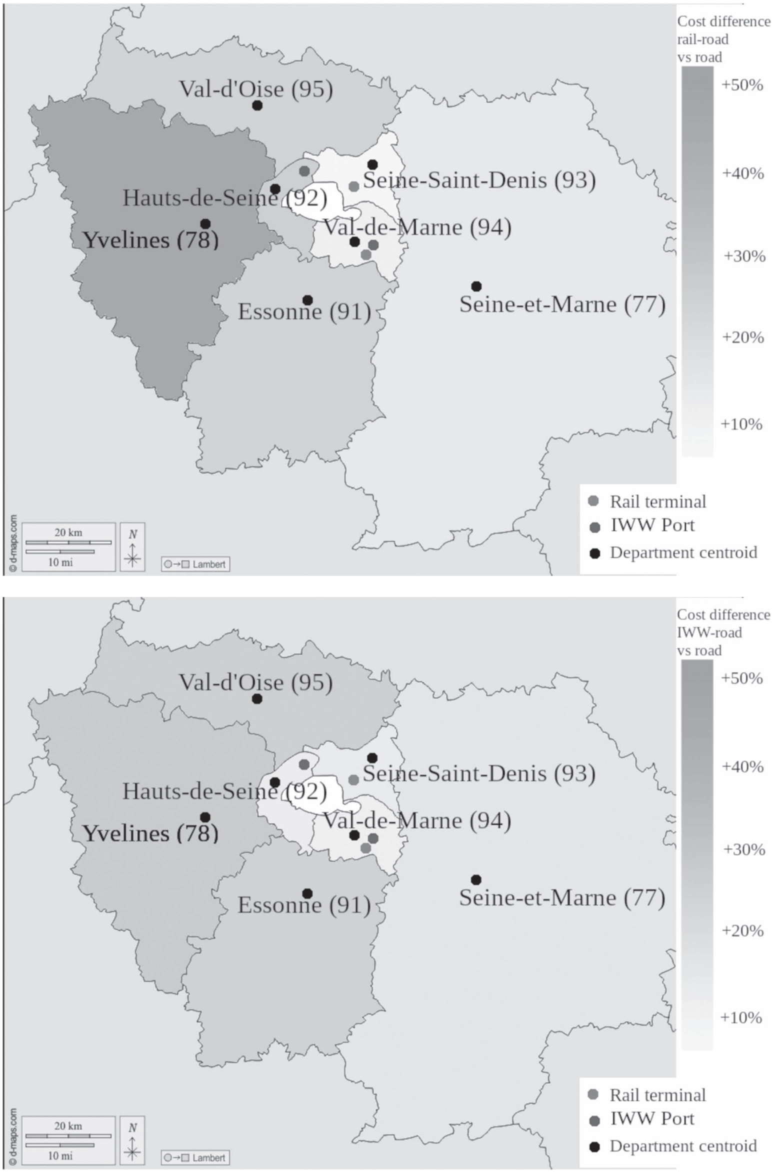


Figure 4.7 Two TEUs per truck: relative difference between intermodal full costs and long-distance road full costs, for rail–road (a) and IWW–road (b). We assume that all traffic originates from the Le Havre port.

the fact, however, that it can be a competitive solution on a local level when the demand is strongly concentrated around the terminal. We can note two studies in this domain that yield markedly different results.

First, Bouchery and Fransoo (2015) set out to find the best location of road–rail terminals in a theoretical hinterland, optimizing either total cost, carbon emissions, or seeking the greatest modal shift. In their work, the authors assume a spatially uniform distribution of demand. They highlight a number of mathematical principles, such as the optimal location of the terminal according to the various cost parameters or the conditions for running cost-effective trains over short distances. Still, the authors' research methodologies differ greatly from our own. On the one hand, the numerical application they propose is incomplete. Certain parameters are not defined (demand density for instance), and the costs set by the researchers are questionable (e.g. the cost of road transport has no fixed component corresponding to truck-loading time, and the cost of rail transport has a fixed component that depends on distance, but no fixed component that is independent of distance, corresponding, for example, to the provision of a locomotive and its driver). In addition, and even more importantly, demand along the Seine is not at all uniformly distributed in space, so much of the divergence in results can be explained by this assumption.

Second, a project led by Université Le Havre studied the link between the port of Le Havre and a terminal in Moissy-Cramayel in the Paris region, focusing on post-haulage optimization (Benantar et al., 2020) and a new type of terminal (El Yaagoubi et al., 2022). Though both of these aspects of the logistics network are worthy of investigation, and the results show that intermodal transport alternatives could prove more cost-effective than road transport, there is a lack of data to corroborate these conclusions. Indeed, the authors fail to indicate road and rail costs, whether it be in their structure or in their level. Nor is the method of calculating the costs of each mode provided; the same is true for the costs of building and operating the terminal. In short, it is as if the optimizations of these two domains alone were enough to solve the competitiveness issue. These papers focus primarily on the optimization of the two problems studied (operational research), and so it is difficult to comment on their economic conclusions. In the study by Benantar et al. (2020), however, we can note that the customers served around the commune of Moissy-Cramayel are not correctly located with respect to the terminal: they are located towards the west of the terminal, whereas they should be located in the terminal's market area, a competitive economic area, which is situated to the east (Niérat, 1997).

Over short rail distances, terminals have a small market area, and they can only serve customers in their immediate vicinity (Niérat, 1997). It may be worthwhile to increase the number of nearby terminals by placing them closer to shipper-dense areas to capture a share of their traffic. However, it remains unclear whether the volume of local traffic is high enough to justify the use of block train technology, which is the only rail-based solution that can achieve a reasonable level of profitability (Hintjens et al., 2020). Hence, until railroads can find a viable way of supplying low-volume terminals, it is unlikely that intermodal transport will develop in situations such as those analysed in this chapter.

Our study takes a critical look at methods of assessing the competitiveness of intermodal transport. The method we have adopted is far from being perfect. There is a strong need for more comprehensive data, as well as better centroids. Centroids, for instance, could be calculated from warehouse density, a method favoured by certain researchers (Vision prospective du développement, 2016). Moreover, rail fixed costs are low, compared with fixed costs proposed by the national France rail company (SNCF) itself. In addition, in our study, transshipment costs are proportional to the number of TEUs, whereas in practice they are proportional to the number of containers. Furthermore, 20 ft containers have roughly the same transshipment costs as 40 ft ones, which is not the case with our formulas.

Moreover, there are certain crucial points that we have not quantified in our study. For instance the Le Havre–Paris route is short, compared to the classic rail–road transport routes such as Paris–Avignon. On the one hand, short distances correspond to smaller market areas (Niérat, 1997) and therefore attract fewer customers. On the other hand, for short journeys, the need for flexibility is greater. Indeed, a trip from Le Havre to Paris takes about 3 hours by truck, so shippers will avoid the time constraints of rail for such a short road transport duration. However, synchromodality (Van Riessen et al., 2015) could be a solution here by reducing the rigidity of intermodal transport.

Also, pre- and post-haulage in intermodal transport can be viewed as a form of road transport over very short distances. We have assumed in our study that the costs are the same as for long-distance road transport, but in reality this is not the case. Very short distances to and from intermodal transport terminals incur additional costs, especially due to congestion and labour costs. Our results undoubtedly paint a picture of intermodal transport that is overly optimistic.

That said, a certain degree of uncertainty is unavoidable – the distance of long-road trips, for example, is highly variable and will depend on the route, the time, and many other unpredictable parameters. The uncertainty range is so wide that it is comparable to distances between departments in the Paris region. Therefore, to a certain extent, road distances between Le Havre and the Paris region departments can be considered as being identical. As a result, assessing the road costs with sufficient accuracy proves challenging.

Conclusion

In this study, we highlight the importance of the first and last kilometres in intermodal transport. Shipowners manage to lower their costs by consolidating river flows, but depending on the position of the Île-de-France destination, the price of doing so can increase significantly. This economic factor may explain why intermodal transport is struggling to gain traction and offers insights into avenues for future development.

The method selected for this study has the advantage of being comprehensive, since all cost elements are provided. Nevertheless, this approach is inherently restricted by the availability of relevant data. Our data are meshed at the departmental level, which leads to a cost estimate for each department. As these departments are large, the centroid is far from the terminals, and the costs of alternatives to road transport are high. More detailed data analyses would allow for a more refined breakdown of results and would likely reveal areas where intermodal transport could prevail as a competitive transport solution.

Finally, in this work, we also analysed the feasibility and value of our proposed research method. Indeed, the costs used in this study present several shortcomings: transshipment, for example, has a cost expressed in €/TEU, assuming therefore that the transshipment of a 40 ft container will cost exactly twice as much as that of a 20 ft one. However, this is not necessarily the case. In addition, the cost of post-haulage does not account for optimization possibilities (the number of customers handled per day, loaded trip rate, etc.). These issues will need to be resolved in future investigations.

Note

1 Hintjens et al. (2020) draws on the "Handbook on the external costs of transport" provided by the Publications Office of the European Union.

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5 The new Le Havre–Serqueux–Gisors–Paris rail freight corridor

Is France on track to improve the competitiveness of the port of Le Havre?

Laurent Guihéry

Introduction

Most European ports in the Northern Range have developed a rail corridor strategy linking their port – and sometimes even their berths, as is the case in Rotterdam – with their hinterlands. In doing so, these port facilities aim to: increase and standardize flows using rail transport; ensure the safe movement of hazardous materials, which cannot be transported by road; and ship very large volumes of containers, which sometimes saturate the storage facilities of ports, to their respective hinterlands. In addition, from an environmental point of view,[1] by opting for these rail corridors, nations can significantly reduce the amount of greenhouse gas emissions which result from transport by road, or even by river, and therefore move a step closer towards the European Union's objective of carbon neutrality by 2050 (European Commission, 2011). This strategy holds much promise, not only in terms of results from academic research but also in view of the successful experiences in certain European countries, such as the Netherlands with the Betuweroute.

Can the same be said about France and its major harbour, the port of Le Havre? In stark contrast to the modal split of combined transport in the Northern Range ports, the port of Le Havre ships only 4% of its containers by rail, with 86% of flows being transported by truck. This constitutes a major failure in the national strategy of reducing CO_2 emissions in France and in the European Union's objectives in terms of shifting freight from road to rail (ibid.). In an attempt to resolve this issue, in March 2021, SNCF Réseau, with the help of the Normandy region, the French State, and the European Union, opened a freight corridor between Le Havre, Serqueux, Gisors, Pontoise, and Paris. The SNCF has announced that, with this new corridor, rail services between Normandy and the Île-de-France hub will be able to operate an additional 25 train paths per day. This capacity will benefit not only the port of Le Havre but also the port of Rouen. In concrete terms, if proposed plans are achieved, this will mean more than 6,000 fewer trucks per week on the roads. What expectations do public authorities, freight forwarders, and rail operators hold for this new rail corridor? How do initial operating results measure

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up? What are the advantages, as well as the stumbling blocks, of using this new corridor? This chapter will attempt to offer some answers to these questions.

Since this corridor represents a recent infrastructural development, the research methodology used in this study is primarily based on the following: data and interviews with operators and beneficiaries of the corridor (SNCF Réseau, Naviland Cargo Le Havre, Regiorail, Groupe Combronde/Ferovergne); round-table discussions and exchanges with elected officials and citizens (meeting with the local population at Pontoise, meeting with the mayor of Herblay-sur-Seine); and a press and literature review to provide bottom-up information to assess this new infrastructure.

The port–corridor–hinterland strategy and lessons from abroad

In the 2010 paper entitled "Functions and actors of inland ports: European and North American dynamics," Rodrigue et al. analyse the role and function of inland ports as a major actor in the supply chain. They consider that the existence of a rail or river corridor is one of the three main criteria (alongside containerization and massification of transport) that are fundamental in the definition of inland ports. Rodrigue et al. describe this first criterion as a "dedicated link" and explain that "[a]n inland port must be linked with a port terminal with a high-capacity corridor. Although truck shuttle services can be used, rail or barge dedicated links are the best options" (p. 519). The different models for linking inland ports to the hinterland or the supply chain are all corridor-based, as shown in Figure 5.1. This is the case for the satellite model – a "facility located in relative proximity to a port terminal" – and the load centre – "an intermodal rail or barge terminal enabling access from a port terminal to a regional production and consumption market" – as well as for the transmodal centre – "a more marginal transport function where an inland port links large systems of freight circulation either through the same mode

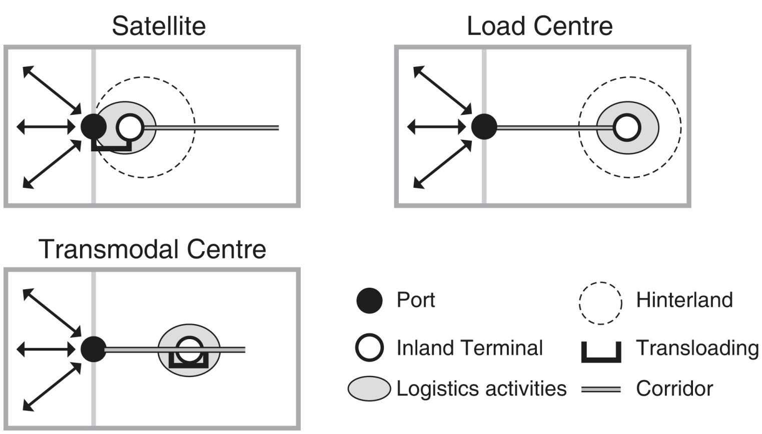

Figure 5.1 Types of inland ports.

Source: Rodrigue et al., 2010, p. 521.

(e.g., rail to rail) or through intermodalism (rail to truck)" (p. 521). The freight corridor is therefore the cornerstone of effective supply chain organization of flows in the hinterland.

The relevance of the port-corridor-hinterland strategy has been explored in numerous publications, which highlight the combined role of a rail corridor and its corresponding port. Guerrero (2019) summarized the results of various publications that cover this topic such as Merk et al. (2011); Coopération des agences d'urbanisme (2017); Kerbirio and Serry (2020); Fraser and Notteboom (2014); and Wilmsmeier et al. (2011). In this analysis, Guerrero wrote that "[c]ontainerization has challenged the hypothesis of captive hinterlands that are spatially concentrated around ports" and that we have seen "[n]ew kinds of liner shipping services such as those organized as hub-and-spokes networks, involving an increasing concentration of flows" (2019, p. 541).

In practice, the model for this strategy is the Betuweroute between Rotterdam and Venlo. The Betuweroute is a double track freight railway spanning 160 km, starting in the port of Rotterdam, across a 48-km distance, and running along the A15

Figure 5.2 The Betuweroute: from the port of Rotterdam to the German border.

Source: ec.europa.eu.

freeway for 115 km to the German border in the east. Here, it connects to Emmerich (Germany) and to the large river inland port of Duisburg, a hub of German and international logistics flows, as a possible exit for the trains coming from China's new Silk Roads, for instance (Figure 5.2). The Betuweroute was partly financed by the European Union, and, under pressure from local residents and environmentalists, required the construction of 20 km of underground tunnels and more than 130 bridges or viaducts. Its final budget was €4.7 billion, compared to the initial projected cost of €1.1 billion. In 2011, traffic increased by 30% to 23,000 trains, and Keyrail, the infrastructure manager, set a target of 500 trains per week in 2013. Container traffic accounts for the largest traffic share – more than 50%. The resounding success of the Betuweroute has translated to less traffic congestion, fewer accidents, and reduced levels of pollution along motorways and in the surrounding landscape. In addition, it has led to safer transportation of hazardous materials, massification of flows, and a rapid connection to long-distance supply chain networks.

Figure 5.3, taken from Rodrigue et al.'s article published in 2010, shows the different actors involved in the operations of the Betuweroute, which forms a central rail axis between the port and the hinterland and offers a network of extended functions (take the trimodal container management terminal in Venlo, for example, which provides services such as customs clearance, container shipping, connections with European distribution centres, transshipment to trucks). The satellite terminal in Venlo is an extension of the port, reinforcing the port's specialization on the sea–land interface and giving the hinterland satellite all the accessory functions of container management (Rodrigue et al., 2010, p. 525).

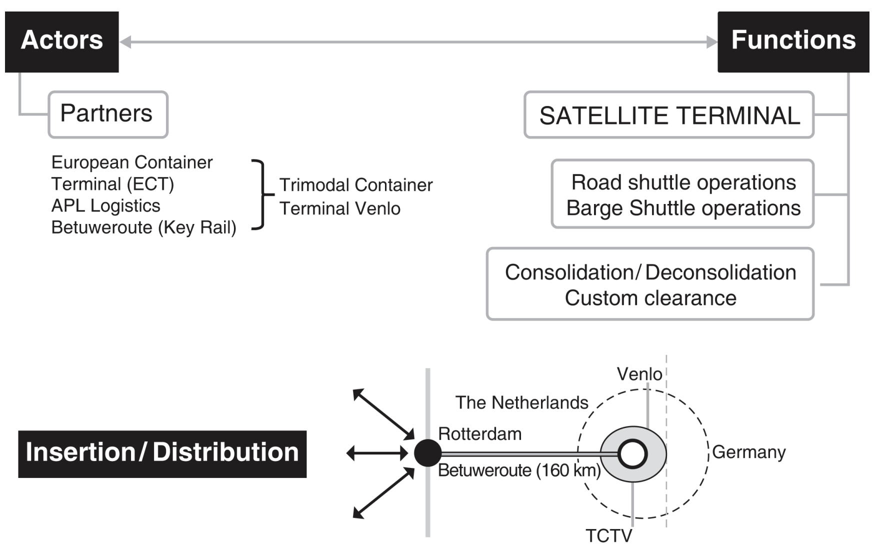

Figure 5.3 The actors of the Betuweroute.

Source: Rodrigue et al., 2010, p. 525.

In Belgium, the port of Antwerp is seeking to develop a link to its hinterland by reactivating, with the help of Infrabel (a government-owned public limited company responsible for the Belgian railway), the Steel Rhine link[2] between Antwerp and Germany (Guihéry & Laroche, 2015; Frank Witlox, 2006). This link crosses the Dutch province of Limburg, much to the dismay of the Dutch – home of the port of Rotterdam, Europe's leading seaport – who are keen to hang onto this much-coveted position. At the time of writing in 2022, Flanders and North Rhine–Westphalia in Germany continue to push for the reopening of the Steel Rhine. The current energy crisis could help move the negotiations forward with the Netherlands.[3] On the German side, Bremerhaven and Hamburg also rely heavily on rail transport to move their containers out of the port by rail.

Thus, the share of combined transport carried by rail stands at 10% in Rotterdam, 7% in Antwerp, 43% in Hamburg, and 43% in Bremerhaven. In contrast, the port of Le Havre ships only 4% of its containers by rail, with truck freight making up 86% of its flows (and barges 10%), compared to 51% in Rotterdam and 57% in Antwerp. In 2017, Hamburg carried 2,333,774 containers by rail, which represented a 1% increase compared to 2015. In Rotterdam, the figure stood at 915,000 containers, an increase of 3% compared to 2015, while in Antwerp, 476,000 containers were carried, an increase of 14% over the same period. Bremerhaven hit the total of 1,134,000 containers moved by rail (+5% since 2015).

In addition, these corridors contribute towards European transport policy, which aims to open up infrastructure to new rail freight entrants through an "open access" model (Railway Gazette, May 2016). On the Betuweroute, therefore, more than ten European rail freight operators are competing to serve the whole of Europe and mainly countries such as Germany. Certain innovations have already been implemented, such as the new rail signalling standard supported by the European Commission, the European Rail Traffic Management System (ERTMS), which is now present on the Betuweroute.

Decarbonizing freight transport: will Le Havre get left behind in the race for a modern rail freight corridor?

This idea of creating a link between the railroad and the port was arguably first conceived in Normandy in the nineteenth century. Indeed, in September 1850, Alexis de Tocqueville,[4] as president of the Conseil général de la Manche, the government body administering the department of Manche, welcomed the prince-president Louis-Napoleon Bonaparte to Cherbourg. On this occasion, Toqueville "called forcefully for him to establish a rail connection between the Norman port town and Paris" (Zunz, 2022, p. 321). Toqueveille's main argument rested on "making the railroad line a natural extension of Cherbourg harbor, which already handled about a quarter of all French imports" (ibid.).

But today, keen to improve its competitiveness, it is in Le Havre that the idea of a port–rail interface comes to the fore. Indeed, this major French harbour occupies a prime position in the Northern Range, precisely because of its position as the first deepwater port opening directly onto the English Channel. It is also located at the outlet of the Seine Valley and boasts a trimodal service offer – waterway, rail, and road – used to serve the large consumption area comprising Île-de-France and Normandy, as well as production facilities along the Seine Valley. The Haropa port complex, an economic interest grouping (EIG) between the ports of Le Havre, Rouen, and Paris (hence the acronym) created in 2012,[5] has experienced substantial growth in recent years: some 3.10 million TEU (twenty-foot equivalent unit) containers were handled in 2021,[6] mainly through the Le Havre terminals, positioning the port of Le Havre as the number-one port in France and the fifth most important port in Northern Europe in terms of container transport. This complex saw a 28% growth in 2021 after a 16.5% drop in 2020, a year marked by the health crisis and social conflicts surrounding the "Ports Morts" ("dead ports") operation led by the Confédération générale du travail (CGT) (General Confederation of Labour), one of the largest trade unions in France. Le Havre handles 6.5% of all the containers shipped from Le Havre to Hamburg (Buyse & Garnier, 2022). However, a key issue remains – the modal share of rail: Haropa's modal share in tonnage for rail stands at 10%, compared to 8% in Rouen and 11% in Le Havre, where the share of combined transport is 5%. In addition, the quality of service on the Seine Axis is poor, largely because it is saturated by high volumes of Transilien and mainline passenger trains from Normandy, but also because of the large-scale work around Mantes-la-Jolie following the commissioning EOLE (Est Ouest Liaison Express) (East West Express Link) project to extend the RER E network. The RER E is one of the five lines in the Réseau Express Régional (Regional Express Network), a hybrid commuter rail serving Paris, France, and its suburbs.[7] This extension of the RER E is intended to relieve the many passenger flows in the western part of the Île-de-France region. Indeed, it is estimated that in 2024, there will be twice as many passenger trains passing through Mantes-la-Jolie than in 2022. According to recent data studying the link between Mantes-la-Jolie and Paris (55 km), a total of 620,000 commuters and passengers have been recorded using these services. As a result, running additional freight trains alongside these routes is proving very difficult (Île-de-France mobilité, 2022).

Solutions for the containers shipped to the port of Le Havre

Many actors have pledged to strengthen the attractiveness of the port of Le Havre within the framework of the Haropa venture: Haropa will have a 17-member supervisory board, including five representatives of the French State; four leading figures from the economic world; elected officials from the regions of Normandy and Île-de-France; and elected officials from the metropolises of Le Havre, Rouen, and Paris. A Seine Axis steering committee will be responsible for informing the strategic decisions of the supervisory board, while each port will retain its own development council to represent local interests.[8] On a more regional level, SNCF Réseau should be able to meet the expectations of public authorities in terms of reducing CO_2 emissions in transport. The regions of Île-de-France and Normandy, for their part, actively support the development of the port of Le Havre, at a time when competition with the ports of the Northern Range is fierce. The region of

Normandy also aims to offset the impact of the Seine Nord project and plans to link Antwerp with the Île-de-France region, which could erode a significant part of the port of Le Havre's container traffic.

In March 2021, SNCF Réseau completed a new rail line through the northern Seine Valley connecting the port of Le Havre to the Île-de-France region via Motteville, Montéroliet-Buchy, Serqueux, Gisors, Pontoise, and Paris – Valenton (Figure 5.4). Using this line, you can reach the Île-de-France region in 3 hours 45 minutes, compared to 3 hour 35 minutes via the Seine Valley (when the tracks are available, and when there is little traffic congestion). This rail line is in fact a sort of renaissance, harking back to the route's heyday back in the nineteenth century where it offered a direct link between Paris and Dieppe, attracting a large number of English and Parisian tourists, particularly for sea bathing. Moreover, on 29 March, the Normandy region took the opportunity to reintroduce a TER service between Gisors and Serqueux, offering two return trips in the morning and two in the evening Monday through Friday (Rail Passion, 2021). At the time of writing, in mid-2022, traffic is very low, according to the local press. The Normandy region is also looking into creating a direct link between Gisors and Rouen.

The long-awaited French freight corridor: on the horizon at last?

Major works have been carried out by SNCF Réseau, for a total budget of €246 million. The Normandy region and the French government have each provided

Figure 5.4 The new Serqueux–Gisors freight corridor.

Source: La Direction régionale de l'environnement, de l'aménagement et du logement (DREAL) de Normandie, (The Regional Directorate for the Environment, Planning and Housing of Normandy). www.normandie.developpement-durable.gouv.fr/ligne-ferroviaire-serqueux-gisors-a3226.html

€90 million in funding. The European Union, for its part, has contributed €66 million, in comparison with Haropa port's first annual turnover, which was set to reach 350 million € in 2022.[9] The line was declared to be a matter of public utility on 18 November 2016. Track upgrades were completed in March 2021.

Although this corridor presents a slightly longer travel time than the Seine Valley – a travel time of 3 hours 45 minutes, compared to the 3 hours 35 minutes for an equivalent journey via the Seine Valley – it does offer considerable traffic capacity with available train paths (Figure 5.5).

Prior to these improvements, the line was not fully electrified, and there was no direct connection. A ground agent was therefore required to operate this connection, constituting an additional cost for the railway.

Two thousand catenary poles were installed to electrify the missing links, 34 switches were modified, and a new 1.3 km long comma-shaped track was built to facilitate the connection to Serqueux, eliminating the need to reverse the train (see Figure 5.6).

In addition, nine level crossings have been removed. The removal of these crossings means that some smaller municipalities in Normandy, whose budgets are more limited, have been forced to modify their urban transport plans. Local actors

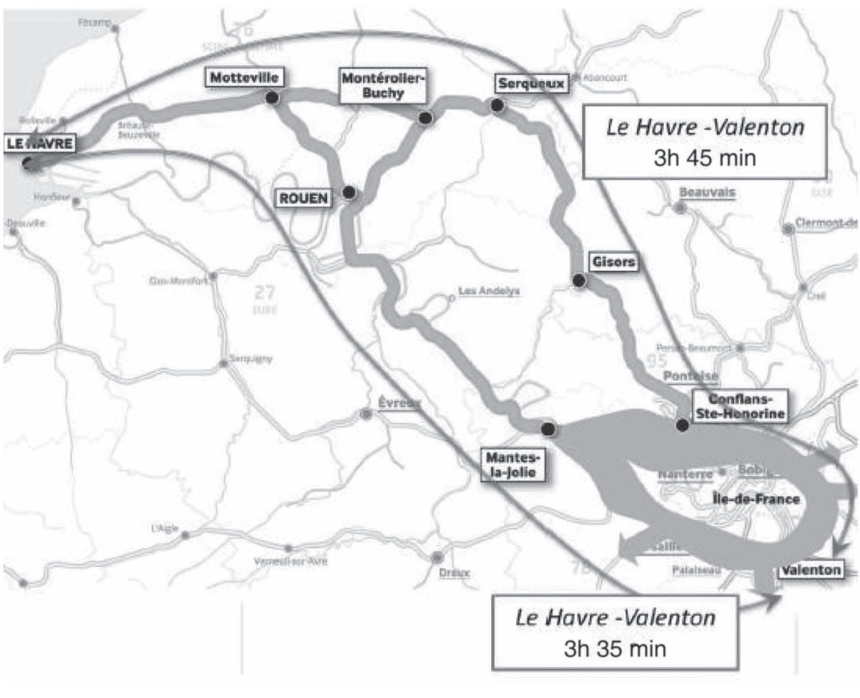

Figure 5.5 New corridor and Seine Valley travel times and capacities.

Source: SNCF Réseau; in green: capacity greater than or equal to 1.5 times of requirements; in orange: capacity greater than or equal to requirements.

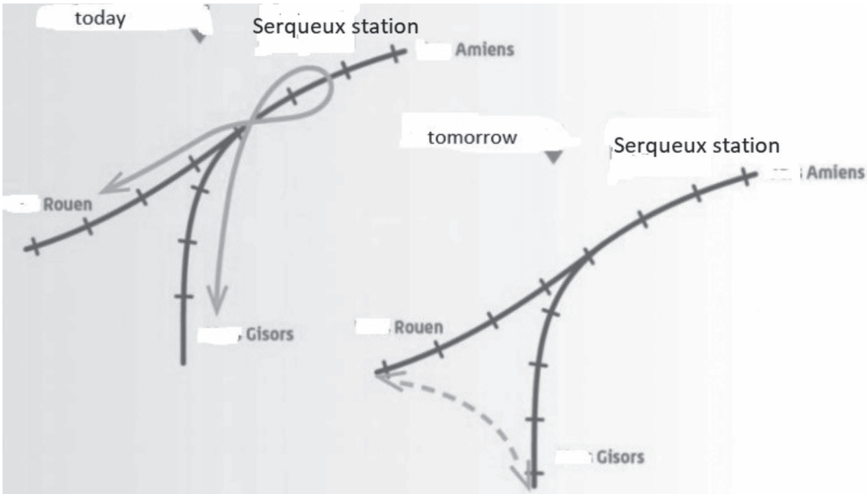

Figure 5.6 The Serqueux comma.

Source: SNCF Réseau.

will therefore have to find alternative ways to organize their routes and cross the railway line. National decisions on infrastructure building have had direct impacts on jurisdictions in Normandy, and they have rarely proved particularly beneficial, except in terms of reducing noise and vibrations for residents. It is for this reason that, alongside freight transport, a new service of passenger transport was also proposed between Serqueux and Gisors in March 2021. Four direct daily round trips were introduced from Monday to Friday (article from the newspaper *L'Impartial*, 29 March 2021).[10] More than 100,000 hours of labour went into making this corridor a reality.

Signalling is now automatic, and traffic can operate 24 hours a day. Trains entering the Paris region should therefore pass through Pontoise, Conflans, and Argenteuil, providing access, via the Grande Ceinture line, to the logistics platforms at Le Bourget and Valenton. And yet, the first recorded levels of traffic show that rail companies are struggling to get used to this new route. In November 2021, SNCF Réseau recorded 53 trains in 33 different timetables over 30 days, including 22 days of traffic, that is, just two to three trains per day, whereas the capacity announced by SNCF Réseau was 25 trains per day (half day, half night). In November 2021, there was no traffic between 10 p.m. and 3 a.m., and nothing on Sundays. The railway companies that have made use of this route are as follows: Regiorail, Fret SNCF, Lineas France, Naviland cargo, Esifer, Port de La Rochelle, Millet Rail (Colas Rail).

SNCF Réseau has published the track access charges for this rail route (see Figure 5.7). These fees are approximately €100 higher than the access fees charged for the Seine Valley route, which, according to the various operators consulted, is a major stumbling block for its development. The profitability of long-distance rail

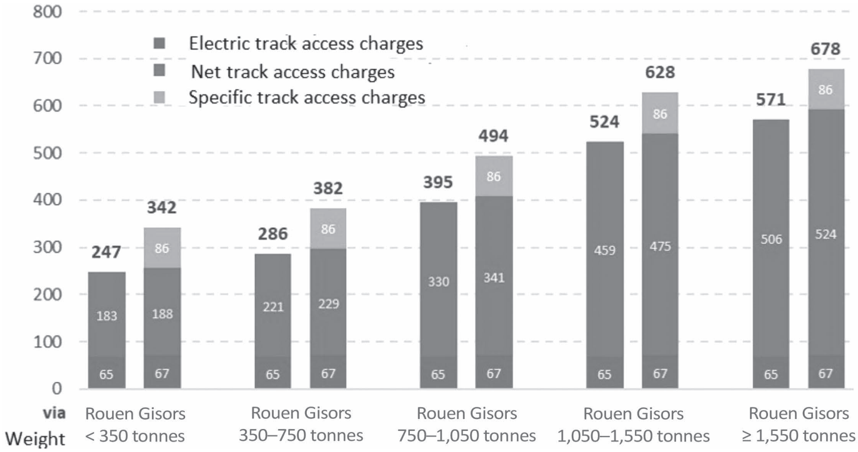

Figure 5.7 Infrastructure usage charge for a freight train between Paris and Le Havre according to its weight and route (Seine Valley or Serqueux–Gisors) in 2022.

Source: SNCF Réseau, S. Seguret.

freight transport is very limited in France, and shippers keep a close eye on the track costs on different routes. When Getlink (ex-Eurotunnel group) proclaimed itself to be "the only profitable rail freight operator in France,"[11] it in fact painted a very accurate picture of the current rail freight market.

Moreover, the route of this rail line which, on its way to the Paris region, crosses the affluent region of Vexin, with its population concentrated along the railroad line, has sparked a wave of protests from local residents.[12] Local residents' groups, supported by the president of the Île-de-France region, the mayor of Pontoise, and the mayor of Herblay-sur-Seine, have severely criticized SNCF Réseau for their lack of consultation and are demanding that solutions be found to address the noise pollution caused. On 8 November 2021, the Prefect of the Val d'Oise deemed the Pontoise rail crossing to be "very noisy." Appeals to the Conseil d'Etat, France's highest administrative jurisdiction, have already been lodged. SNCF Réseau has voiced its concerns about this issue and is taking steps to reduce the rail noise caused by these freight trains. In February 2022, some local residents' associations circulated a questionnaire on the impact of railway noise felt by residents following the arrival of these freight trains on the Serqueux–Gisors line. Large infrastructure programmes often come up against strong opposition in France today, mainly as a result of NIMBY ("not-in-my-backyard") behaviour. This is equally the case for the most important rail freight infrastructure challenge facing modern France: the "Le Contournement ferroviaire lyonnais" (CFAL) (South Lyon rail bypass), a proposed new twin-track system for freight and passenger trains, which is still awaiting construction 20 years on.

What are the prospects for the Serqueux–Gisors freight corridor?

In theory, this corridor holds much promise. First, it aims to provide the Le Havre harbour with a viable alternative to road freight, which accounts for most of the port's outbound flows. Second, this corridor should enable the port of Le Havre to improve its carbon footprint and to meet the sustainable development objectives set out by the European transport policy. Third, it ought to allow Le Havre to become part of the new European dynamic, much copied abroad (China), of a "port–corridor–hinterland" supply chain strategy. It would also connect Le Havre with the new Eurasian Silk Road links between Europe and China (Lasserre & Mottet, 2021).

However, traffic levels remain low, and the opposition voiced in the Île-de-France region against its launch have dampened public support for the corridor. It seems that today, the corridor has been assigned the role of a back-up route, called upon when the Seine Axis is saturated or under construction, as was the case in 2022 when works for the EOLE project to Mantes-la-Jolie were completed. This situation is indeed regrettable.

There are several reasons behind the reluctance of railway companies to use this corridor:

- The use of this corridor requires train drivers to reorganize themselves and learn new routes. It also requires rail operating staff and ground handlers to change their working habits in relation to the Seine Axis. In addition, this corridor requires a new location of relay points for driver changes and a new organization of cab or service car routing for the train drivers. In short, it is a question of routine: it is difficult for rail companies to break out of their well-established habits and their familiarity with an existing route. Questions are also being raised about opening up the logistics platforms at the end of the line.
- The track access charges are about €100 more expensive than alternative lines, limiting the attractiveness of the new Serqueux–Gisors freight rail corridor, since cost reduction is currently a top priority for railway companies.
- In terms of size, the trains running on this corridor are only 750 m long, as opposed to the 850 m long trains that operate on the Seine Axis (which can carry about 50 containers). The speed of these trains is limited to 120 km/h. Their tonnage is also more limited: 1,700 tonnes compared with 2,100 tonnes for trains on the Seine Valley – that is 400 tonnes less, a significant difference. There may also be a problem of gradients (10°/°° on Serqueux–Gisors compared to 8°/°° for Le Havre–Paris via the Seine Valley).
- Finally, the exit from Le Havre, in terms of railroad towards the Serqueux–Gisors corridor, appears problematic, having only one track and presenting a risk of bottlenecks.

Second, there is also the issue of path saturation during the day, with major difficulties experienced at Pontoise and Argenteuil for the Serqueux–Gisors route, as well as with the EOLE works in the Seine Valley. Given its current position, Haropa is therefore increasingly homing in on river transport solutions.

Conclusion

Though very encouraging on paper, with promises from the SNCF that it would result in the removal of 6,000 trucks per week from the roads on the Seine Valley – one of the most congested corridors in France – the first year of operation of this new rail freight corridor tells a different story. Indeed, this corridor is mainly seen as a "back-up" route, and preference is still given to the main Seine Valley axis. For example, between Thursday, 26 May, at noon and Sunday, 29 May, at 4 p.m., that is for almost the entirety of 2022's Ascension Day four-day weekend, traffic was completely cut off between the stations of Mantes-la-Jolie and Vernon on the Seine Axis. As a result, all trains bound for Le Havre, whether freight or passenger, opted for an alternative route: the Serqueux–Gisors line.

One of the mainstays of the shift to green transportation in France is the modal shift from road to rail (European Commission, 2011), and the new Le Havre Serqueux–Gisors–Paris corridor is clearly forging ahead towards this objective. And yet, currently, for reasons of noise pollution, vibrations, and NIMBY behaviour, residents and cities alike are very reluctant to pledge their political support and to welcome new services on this route. And so, the development of French rail freight is still a far cry from major corridors like the Betuweroute in the Netherlands. It appears that in terms of the massification of freight flows, containerization, service quality in rail operations (punctuality, reliability), and the availability of platforms at the corridor exit (Paris), France has a long road ahead.

Notes

1 During the Grenelle Environment Forum in 2009, a commitment was made to increase the modal share of non-road transport from 14% to 25% by 2022. In 2018, leaders at the United Nations Climate Change Conference (COP21) pledged to reduce greenhouse gas emissions by a minimum of 40% by 2050.

2 The classic link, or Montzen Line, named after the German general who promoted it during the First World War is indeed saturated (Guihéry & Laroche, 2015).

3 https://trends.levif.be/economie/la-flandre-et-la-rhenanie-du-nord-westphalie-esperent-rouvrir-le-rhin-d-acier/article-news-1589833.html?cookie_check=1675335092

4 Best known for his book "De la démocratie en Amérique" (Democracy in America), published in 1835.

5 The Haropa merger involves the collaboration of 1,800 employees, including 1,200 in Le Havre and 400 in Rouen.

6 In 2021, Rotterdam: 15.3 million containers; Antwerp: 12 million; Hamburg: 8.7 million; Bremerhaven: 5 million.

7 This project, which consists of extending the current RER line E by 55 km to the west, includes several traffic improvement projects, including the modernization of 47 km of existing tracks to Mantes-la-Jolie.

8 www.lejournaldugrandparis.fr/le-gouvernement-devoile-la-future-gouvernance-dharopa/

9 www.usinenouvelle.com/article/les-ports-de-le-havre-rouen-et-paris-ont-profite-de-la-congestion-d-anvers-et-rotterdam-en-2021.N1779682

10 https://actu.fr/normandie/gisors_27284/eure-apres-le-fret-la-ligne-gisors-serqueux-est-de-nouveau-ouverte-aux-voyageurs_40625709.html

11 www.actu-transport-logistique.fr/ferroviaire/europorte-se-revendique-seul-operateur-de-fret-ferroviaire-rentable-en-france-455991.php

12 For example the Collectif Alertes et Ripostes Fret (CARF) (Freight Alerts and Responses Collective) expressed its concerns about the Serqueux–Gisors rail freight line during a press conference involving local residents and their elected representatives on 13 March 2021 at noon.

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6 Logistics and the globalization of the automotive supply chain

A case study on the parts consolidation centres in the Seine Valley Corridor

David Guerrero, Adolf K.Y. Ng and Hidekazu Itoh

Introduction

Transport corridor policies aim to improve transport efficiency by fostering economies of scale in freight transportation. The objective of these policies is to optimize the use of existing port and surface transport infrastructure capacity by directing demand towards selected routes. This is easier to achieve under certain conditions, such as when a single shipper generates large volumes, or when several shippers of smaller size are geographically clustered. The automotive industry is particularly noteworthy in this regard, as it comprises large-scale car assembly plants and numerous supplier plants, often located in close proximity to each other.

Historically, suppliers were typically located in the vicinity of car assembly plants, and parts were carried over relatively short distances. In the context of recent globalization, however, car manufacturers and suppliers are facing a new set of challenges. Between 2005 and 2019, the share of emerging economies in global new vehicle sales increased from 36% to 49%.[1] To meet this changing demand, car manufacturers have significantly increased their production capacities beyond domestic borders, either by constructing new assembly plants overseas or by extending existing ones (the "off-shoring" phenomenon). Nevertheless, in these fast-growing emerging economies, supplier networks are still underdeveloped, and a substantial share of key parts is sourced from suppliers based in advanced economies further afield. In this configuration, procurement lead times are longer and, in some cases, may even take more than two months for certain vehicle parts. Longer lead times are primarily the result of slow maritime freight, as well as production processes involving parts produced in several locations. Faced with this vast network of suppliers, the organization of supply chains is becoming increasingly complex, resulting in larger inventories and posing a major challenge for car manufacturers the world over. To bring down transport costs and ensure the reliability of these pipelines, car manufacturers use parts consolidation centres (PCCs), or cross-docking facilities, where parts are sorted and packed in containers depending on their destination (Itoh & Guerrero, 2020). In a world where competition is

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increasingly fierce, the effectiveness of distant sourcing strategies plays an increasingly decisive role, both in terms of customer satisfaction, by reducing delivery lead times, and cost reduction, by decreasing stock levels throughout the supply chain.

In this chapter, we will examine the realities of long-distance maritime freight and the movement of goods from advanced economies to emerging markets. To do so, we will consider the examples of two French car manufacturers that have implemented strategies to minimize the time and cost of transporting parts from European suppliers to assembly factories in emerging economies overseas. First, we will highlight the fact that, in order to consolidate the shipments of many suppliers to assembly plants in emerging economies, PCCs operated by third-party logistics providers (3PLs), or directly by car manufacturers, have been built in close proximity to affiliated ports. Next, we will shed light on the functions of this kind of logistics facility. By examining the ways in which these flows are consolidated, we will explore the relationship between shippers, ports, and corridor development. The recent increase of the flows handled by these PCCs opens up new opportunities for corridors to develop value-added activities, such as those identified by Ng and Liu (2014)'s "port-focal logistics" concept. We gathered additional insights into this topic by conducting semi-structured, in-depth interviews with five executives from Renault and Stellantis (PSA Peugeot-Citroën at the time of the interviews) and two executives from Gefco, a 3PL specialized in automotive logistics formerly owned by Stellantis. Thanks to the extensive expertise provided by the interviewees, we were able to obtain key information about the workings of the automotive industry.[2] To ensure that the information gathered was as reliable as possible, comparisons were drawn with the data available on the manufacturers' and 3PL's websites. In the second half of this chapter, we will trace a broad overview of distant sourcing strategies in the automotive industry and present a case study of PCCs in the Seine Valley corridor to explain their role in the logistics networks of French car manufacturers. Finally, we will end this chapter by opening up space for further discussion, as well as drawing our conclusions.

Distant sourcing and its implications for French car manufacturers

Industry growth: emerging economies as a key driving force

With rapidly growing demand and low vehicle penetration, emerging economies are driving the growth of the global automotive industry. Home to close to one-half of the world's population, emerging economies, such as China and India, among others, have been at the forefront of this automotive boom. Between 2006 and 2021, output growth in these regions was so strong that it greatly overshadowed the increases announced in rival advanced economies (Figure 6.1). China saw the most dramatic increase: in 2010, it overtook the United States as world's largest new car market (Wang et al., 2013). Over the next few decades, the sales gap between advanced and emerging economies is expected to widen. This is due not only to the

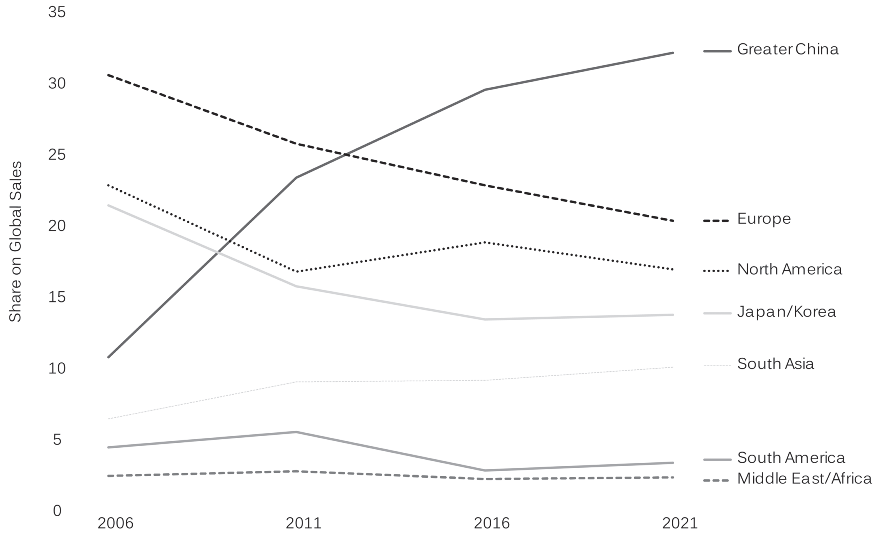

Figure 6.1 Share of global vehicle production by region (in %).

Source: Authors, using data compiled by the l'Association des Constructeurs Européens d'Automobiles (ACEA) (European Automobile Manufacturers Association) (The Automobile Industry, 2022, p. 74).

Note: The term "Greater China" refers to Mainland China, Hong Kong, Macao, and Taiwan. The production volumes of the latter three regions are marginal when compared to those of Mainland China.

large size of emerging economies, but also to their low vehicle ownership rates. In 2019,[3] the number of motor vehicles per thousand inhabitants stood at 816 in the United States, 482 in France, compared to 214 in China and just 44 in India. South American countries fell somewhere in between, with 316 and 366 vehicles per thousand inhabitants in Argentina and Brazil, respectively.

In order to meet ever-growing demand, many car manufacturers have set up new product facilities abroad or significantly expanded their activities at existing sites. Production in these regions has developed in different ways, depending on the distance separating overseas facilities from their domestic production centres. In recent years, we have seen the integration of the Eastern European and Mexican automotive industries into the production systems of Western Europe and North America. The world's other major emerging economies (i.e. China, India, South America, and Southeast Asia) have adopted a variety of trade and investment liberalization policies, together with the creation of protected domestic or regional industries (Humphrey, 2003). On the one hand, quantitative restrictions have been abolished and tariff levels reduced. On the other hand, trade-related investment measures, such as local content requirements,[4] foreign exchange balancing requirements, and duty drawbacks schemes (as well as incentives and subsidies), have been used to stimulate domestic production of vehicles and parts (Humphrey, 2003). As a result, car manufacturers have been investing heavily in assembly plants in emerging economies.

Spare parts pipelines between French car manufacturers and distant assembly plants

The case of Renault

Renault has long been a proponent of the distant sourcing strategy. As early as 1975, Renault set up a PCC in the commune of Grand-Couronne in the Seine Valley corridor, a short distance from other factories the company had launched in the late 1950s and 1960s: Cléon (engines, gearboxes), Sandouville (bodywork, vehicle assembly), Aubevoye (testing facility), and Dieppe (assembly of sports cars and other vehicles produced in small series). The Grand-Couronne PCC was situated halfway between Paris and the port of Le Havre, along the banks of the Seine. In 1971, Renault established a logistics subsidiary, Sofrastock International, to deliver complete-knock-down (CKD) kits from Grand-Couronne to overseas assembly plants. The vehicles were shipped unassembled to avoid the high taxes levied on imports of finished vehicles. In countries where the minimum efficient scale (MES) of production had not been reached, Renault instead invested in the creation of full vehicle assembly plants. In the wake of the expansion of foreign markets, the sourcing system has evolved towards hybrid forms of knock-down (KD), such as semi-knock-down (SKD), where the painting and assembly of kits are carried out in overseas factories in Maghreb, South America, and South Korea. The parts shipped from the PCC are not only those produced by suppliers based in Europe but also those from locations overseas such as Brazil, Japan, and India. Towards the end of the last century, Renault expanded its international logistics network (ILN) of PCCs to Curitiba (Brazil), Cordoba (Argentina), Valladolid (Spain), Mioveni (Romania), Bursa (Turkey), Pune (India), Busan (South Korea), and Tangier (Morocco). In 1999, the alliance of Renault-Nissan paved the way for new opportunities, allowing the two manufacturers to pool their logistics flows. However, over 20 years on, these two major networks, Renault ILN and Nissan PCCs, continue to operate independently.

Since the turn of the century, Renault has been increasingly using an individual part order (IPO) system to supply most of its overseas assembly plants. This entails shipping individual parts from Grand-Couronne ILN based on the requirements of the overseas factories, rather than CKD kits. These parts are procured locally by global and local suppliers. At the time of this study, 15 of Renault's overseas plants were supplied by Grand-Couronne ILN. About half of the parts from 650 European suppliers were repackaged in disposable containers, with varying levels of material resistance depending on the final destination. The average inbound traffic at the Grand-Couronne ILN was 100–150 trucks per day, and the maritime outbound throughput was approximately 10,000, 40 ft equivalent unit (FEU) containers (20,000, 20 ft equivalent units [TEUs]) per year. The FEU containers are carried to the port of Le Havre (90 km away from the ILN), where the variety and frequency of containerized services are much higher than in the port of Rouen. One of the river terminals in the port of Rouen was located close to the Grand-Couronne's Renault facility. Taking advantage of this proximity, river transport from the port of Rouen was used for several years in the late 2000s and the early 2010s[5] to transport FEU containers to the port of Le Havre. However, this service has since been discontinued, with truck freight replacing inland waterway transport. In 2019, the Grand-Couronne site closed its doors, and the ILN activity was transferred to another Renault site in Cléon, less than 15 km from the old site. It is interesting to note that the new facility is far from existing port terminals, making the possibility of a return to river transport very limited.

The case of Stellantis

In the case of Stellantis, global sourcing is a more recent phenomenon. In 2002, during the early stages of its economic recovery and the rapid growth in car sales, Argentina witnessed a surge in local demand for automotive parts. In response, Stellantis called on its 3PL Gefco (Stellantis had a 75% stake in Gefco at the time) to set up a distribution depot in Le Havre (cross-docking) to consolidate the maritime shipments from European suppliers to its assembly plant in Buenos Aires (Argentina) and other overseas plants. By using as much as 90% of container volume, this new system led to a drastic reduction in transport costs. Building on this success, Stellantis used the same channel again shortly after to supply automotive parts to its new assembly plants in Porto Real (Brazil), as well as Shenzhen and Wuhan (China), both operated under a joint-venture agreement with the Chinese state-owned corporation Dongfeng. The logistics network created by Gefco for Stellantis (PSA branch) is known as the Plateforme logistique Internationale (PLI) (International logistics platform) and relied on five PCCs: Le Havre, Sausheim (East of France), Shanghai (China), Trnava (Slovenia), and Mexico City (Mexico).

The system of PCCs at both manufacturers

There is a certain degree of overlap when it comes to the distant sourcing strategies used by the two French manufacturers (Figure 6.2). For example they both rely on PCCs to consolidate their EU-based supply chains. Moreover, the information flow of inbound road transport between the suppliers and the PCC, which could be managed either by the manufacturer (Renault) or by the 3PL (Gefco), is handled by the manufacturers in both cases. Parts are shipped by sea on a weekly basis, thereby improving the fill rate of containers, which are generally unpacked on arrival at an overseas PCC or depot. Empty container restitution is an almost exclusive feature of inland transport, since the reverse logistics involved are particularly hard to achieve when covering longer distances (Guez, 2014).

Overview of the Le Havre PCC (France) operated by Gefco for Stellantis

Approximately 8,000 different vehicle parts are collected from the factories of each of the 800 EU-based suppliers and trucked to Gefco's 38,000 m^2 PCC in Le Havre. A closer look at this PCC reveals three functional classifications:

(a) **Shipments to PCCs**: Parts are transported by truck in different ways, depending on the load size and on the distance from Le Havre. Large consignments,

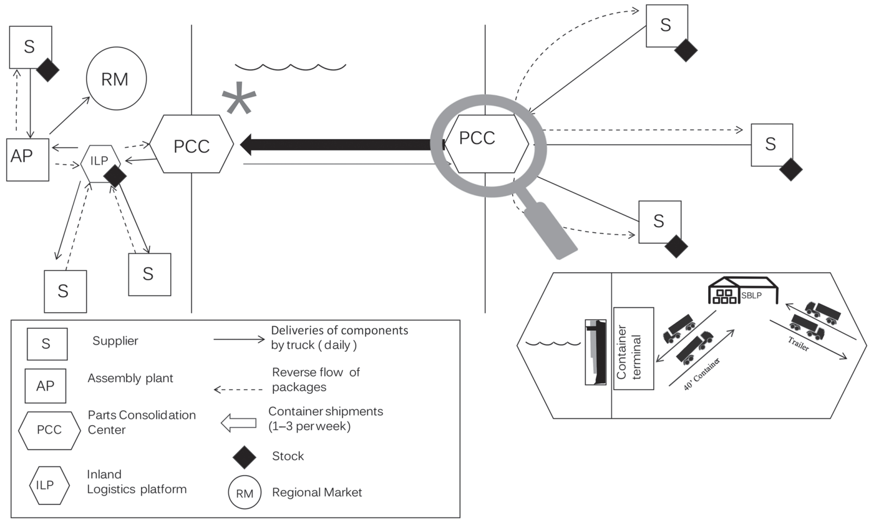

Figure 6.2 Current status of parts consolidation centres in the automotive supply chain.

Source: Authors.

which account for 30% of the cargo handled in the PCC, are shipped by full truckload, mainly from eastern and northern France, the home of several major suppliers. Remaining parts are sourced by other means. The milk run, a delivery method whereby a vehicle picks up loads from different suppliers along a single leg, is used to combine deliveries from several suppliers located in France and in neighbouring countries. When parts suppliers are based further afield (such as Central Europe), light vehicles are used to consolidate the flows of parts onto large trucks via intermediary depots managed by Gefco or by its local logistics partners. This organization generates a considerable amount of empty truck mileage, and the potential for backhaul shipments, beyond container restitution, is limited.

(b) **Operation in PCCs:** Parts are delivered to Gefco's PCC located in Le Havre and subsequently delivered on a weekly basis in disposable packaging to car assembly plants overseas. The average storage time in the PCC is less than 48 hr. Out of the 300 employees, half are temporary staff. The extensive use of temporary workers results from the high variability of PCC activity caused, on the one hand, by the seasonality of production in overseas factories and, on the other hand, by the car manufacturers' management of working capital. Stellantis strives to reduce its working capital as much as possible in the run-up to the mid-year closing process in order to obtain lower interest rates and to finance its debt. As a result, the activity on the monthly PCC breakdown shows a certain degree of fluctuation, with significant drops in May and November (Figure 6.3).

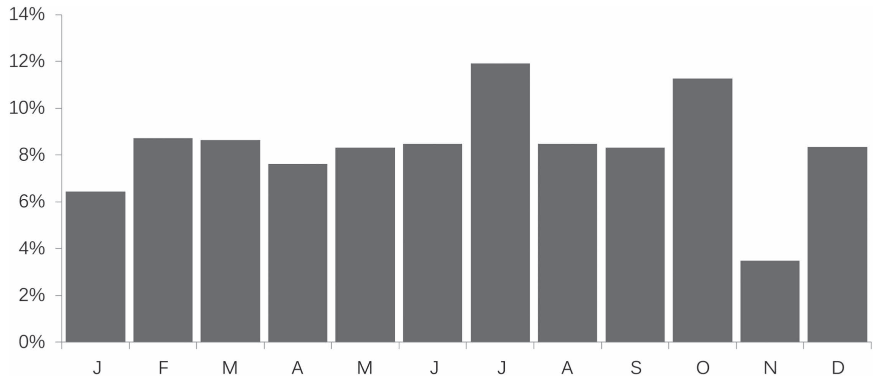

Figure 6.3 Monthly breakdown of Stellantis' handling volumes (% of annual volume).

Source: Authors, based on Gefco data.

(c) **Maritime transport:** From overseas ports, parts are transferred onto trucks and taken to assembly plants or to warehouses and then delivered in small batches and at high frequency to production lines. In 2014, about 8,000 FEU (40-foot equivalent unit) were shipped from the port of Le Havre, of which approximately 22% were shipped to Buenos Aires (Argentina), 36% to Porto Real (Brazil), 2% to Shenzhen (China), and 40% to Wuhan (China). Most shipments were conveyed in dry or high cube FEU containers, and more rarely in reefer containers, widely used in Argentine trade. Maritime carriers are selected directly by Stellantis' logistics department. An alternative pipeline is in place for the emergency supply of parts by air. This supply chain runs from the Le Havre PCC to Charles de Gaulle Airport in Paris and onwards to overseas airports close to assemblers.

The share of parts supplied by EU-based suppliers in car production varies considerably during the production cycle of a given car model. At the start of production, the share of distance sourcing is very high, as global suppliers use the same production facilities in Europe to deliver parts to all assembly plants. This is the direct result of the close relationship between manufacturers and their preferred suppliers, which also means that collaborative design takes place at an earlier stage (Humphrey, 2003). As the volume of vehicles produced by overseas assembly plants increases, manufacturers strongly encourage global suppliers to shift production overseas to avoid import duties, transport and labour costs, and to integrate new components in their local just-in-time (JIT) strategy (an inventory management method in which goods are received from the supplier as and when needed). Local suppliers are brought in at a later stage, partly as first-tier suppliers and mainly as second- or third-tier suppliers. However, the shift from distant to local sourcing is gradual, and optimal levels are only achieved several years down the line. At the end of a car model's production cycle, the local sourcing rate typically falls somewhere between 90% and 95%. Nevertheless, according to the managers interviewed, this figure could be substantially lower for markets in emerging

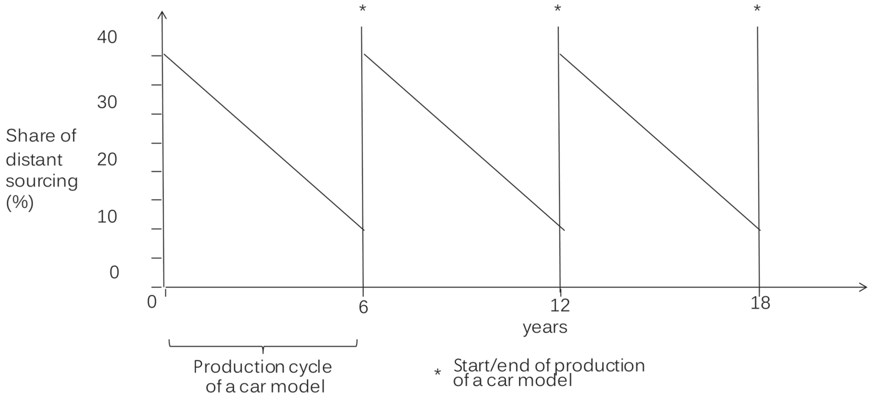

Figure 6.4 Theoretical evolution of distant sourcing for a single car model.

Source: Authors.

economies where the supplier base is much less developed. Figure 6.4 illustrates the theoretical evolution of distant sourcing for an overseas assembly plant. Given that the average production cycle of a car model is five years, the share of distant sourcing (share of parts imported from advanced economies) is particularly high at the beginning of production. After that, if the vehicle model finds a market overseas, suppliers will be encouraged to produce the parts locally to bring down transport costs, thereby reducing the share of distant sourcing. The process is repeated every five years (or more) when a new model is launched overseas.

Is the distant sourcing strategy here to stay? Discussion and conclusions

The analysis conducted in this chapter reveals that a substantial share of the auto parts used in car assembly in emerging economies is sourced from distant regions and that the pipelines of most components are consolidated in PCCs. Does this situation reflect a temporary solution until follow sourcing can be achieved (i.e. suppliers from advanced economies will bring their refined technology directly to the local parts plants in developing economies)? Or is this phenomenon a reflection of a long-term trend in logistics system development? These questions are crucial not only for the companies operating in the automotive supply chain but also for companies and institutions in ports that are benefiting from the extension of automotive supply chains. Given the risks and uncertainties associated with emerging markets, we expect that distant sourcing from advanced to emerging economies will remain at high levels in the years to come. In this scenario, ports will need to handle increasingly large volumes as supply chains increase in scope. However, value creation cannot be taken for granted for every port: most of the related activities will consist of cross-docking and repackaging operations, which do not require the use of specialized skills. Both local institutions and 3PL providers have a vested interest to promote the development of higher value-added activities and could consider directly supporting the enhancement of these flows. When ports and logistics facilities are able to provide high value-added solutions, users will be more likely to call upon their services, which in turn leads to more developed logistics clusters.

As new assembly plants come on stream in emerging economies, the trend towards distant sourcing is also on the rise. Apart from engines and gearboxes, most of the components used in the production of hybrid and electric vehicles are similar to those used for conventional (internal combustion engine) vehicles (Klier & Rubenstein, 2021). PCCs play a key role here, ensuring vendor consolidation and inventory management. Suppliers tend to opt for overseas sourcing for many automotive components, but we are also seeing a movement towards long-distance parts sourcing from European suppliers, particularly for complex or high-tech components. As suppliers expand into emerging economies, the location of their research and development within the global network will take on greater importance. If key components, such as engines, gearboxes, and electronics components, can be sourced locally in emerging markets, to what extent will long distances need to be covered to source from advanced economies? For instance, MES has not been reached for most of the key parts required to implement these follow sourcing strategies (i.e. production volumes of new cars are too low to justify setting up a new supplier plant in the emerging nation). The only exception may be China, where the huge market and presence of spare parts suppliers are important drivers for the implementation of follow sourcing strategies. In other emerging economies, such as Brazil and North Africa, market size and stability do not appear to be sufficient, and caution is warranted.

For the Seine Valley corridor, the opportunities to capture value in automotive supply chains are there for the taking but depend very much on the location and type of vehicle propulsion system. Since vehicle customization takes place close to the final market, it appears that ports of destination for parts are better positioned than departure ports (Carbone & De Martino, 2003; Dias et al., 2010). Still, the introduction of new types of propulsion system, such as hybrid and electric cars, is bringing new opportunities to European ports. For example, electric batteries imported from East Asia by Stellantis for its hybrid vehicles are charged at Gefco's PCC in Le Havre. Although these value-added activities are still marginal, representing less than 3% of PCC activity, with the growth of other large technology-intensive components imported from abroad, there is scope for further development. In this chapter, we examined parts consolidation for car manufacturers located relatively close to a port, but it might also be worth studying other spatial configurations, in other parts of the world, such as a car manufacturing region equidistant from several rival ports, as seems to be the case in Bavaria (Germany) or Wuhan (China).

The information presented in this chapter should not be construed as conclusive assertions about the current and future logistics approaches of car manufacturers. Other aspects, such as shifting power relations with large parts suppliers, and the development of emerging technologies – such as 3D printing – will certainly have an impact on the strategies adopted. Indeed, we are seeing an increase in the possibility of "reshoring" – the decision to move offshored activities back to home territory, such as Trump's "America First" policy during his time in office – and "friend-shoring" – manufacturing and sourcing in countries with shared values, such as the establishment of the Regional Comprehensive Economic Partnership (RCEP) trade agreement effective in January 2022 or the launching of the Indo-Pacific Economic Framework (IPEF) announced by President Joe Biden in May 2022. There are various reasons for this: increasing rivalries in global politics, the impacts of the COVID-19 pandemic, and the recent Russo-Ukrainian conflict. As a result, the future of global supply chains and, indeed, global value chains, is presented with a series of new opportunities (and challenges). Nonetheless, our findings clearly show that distant sourcing from advanced economies to emerging ones is set to be a lasting feature of the automotive industry and that ports have a key role to play in ensuring its continued development.

Notes

1 Data retrieved 24 November 2022 from the OICA website: www.oica.net
2 Since the actual volumes of parts traded, transport costs, and other quantitative data were confidential, we were not able to carry out a quantitative analysis based on the data provided by the interviewees.
3 Data retrieved from various sources: France, Eurostat 2019; USA, Highway statistics 2019; China, Autonews 2021; India, MoRTH 2021; Brazil, Frota de veiculos 2013; Argentina, World Bank 2013.
4 Local content requirements (LCRs) are policy measures that require a certain percentage of parts used in the production of vehicles to be sourced from domestic suppliers.
5 Renault, l'option fluviale, Le Télégramme, 1 June 2007.

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Second section

Geopolitical issues of corridors

7 Competitiveness and geopolitics of port corridors

Laurent Livolsi and Christelle Camman

Introduction

The risks of structuring and managing supply chains have intensified significantly for companies in the aftermath of both the health crisis and, particularly, the war in Ukraine. As a result of the Chinese economic slowdown at the onset of the pandemic and thereafter during the successive waves of infections – with activity grinding to a halt following strict adherence to the government's "zero-COVID" policy – companies are contending with increasing supply difficulties, coupled with a historic increase in the cost of maritime transport. The situation worsened with the outbreak of war in Ukraine, resulting in railroad blockades and airspace closures, causing significant disruption to flight times between Europe and Asia. The war also brought about major inflationary impacts, destabilizing the markets in which Ukraine is positioned, and especially in Russia, which was subject to harsh economic sanctions. As a result, companies are finding it increasingly difficult to secure access to energy, steel, metallurgy, or grain supplies. These ongoing crises are forcing companies to rethink not only about their supply chains but also about their industrial activities to enhance their reliability. However, this transformation is part of a growing trend in business models, where outsourcing is favoured to reduce assets.

Emphasizing the function of companies as essential economic actors, these crises have also had an impact on a state level. In the aftermath of the health crisis, as key vulnerabilities in this area surfaced, the question of the supply of medical and pharmaceutical products has become a major societal issue. The war in Ukraine, by illustrating in turn the difficulties of supply and the risks inherent in outsourced industrial models, has brought the issues related to strategic sectors and, more globally, those of national sovereignty to the forefront of the political scene. The economic retaliatory measures against Russia served as a powerful reminder that companies could be targeted in such situations, where the nationalization of assets belonging to companies from countries viewed as adversaries was a worrying possibility. This underscored the need to develop a dedicated economic diplomacy framework in collaboration with business leaders to navigate such situations effectively. Though this is clearly a step in the right direction, it is important to remember that the Trump administration had previously used the term

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"economic warfare" in relation to China and that it translated to the implementation of an aggressive tax and customs policy.

These ongoing crises serve to exacerbate the economic and geopolitical tensions gripping the world today, particularly in relation to the Chinese "Belt and Road Initiative" (BRI) strategy. By striving for global connectivity, this project of historic proportions challenges established balances of power by reshaping pre-existing global value chains and offering companies opportunities to source and locate their activities in new areas. By enabling companies to operate in closer proximity to their consumer markets and to enhance connectivity, these alternative nearshoring solutions provide a means of securing supply chains while optimizing flow management.

The challenges of securing supply chains demonstrate the need to align public policies with the strategies of companies, particularly those whose operations are closely linked to national sovereignty. Traditionally reserved for the defence sector and other industries with national security implications, the broadening spectrum of sectors affected by supply chain management – from pharmaceuticals, to foodstuffs, and even transport – is a relatively new phenomenon. The goal is therefore two-fold: to ensure the security of strategic sectors and to improve national competitiveness. This inherently involves enhancing the attractiveness of territories and therefore integrating them more effectively into new global value chains. In response to this challenge, major seaports must not only fulfil their traditional role of optimizing the territory's connectivity but also explore the development of industrial and logistic activities to enable more secure supply chains. This issue will form the focus of this chapter, as well as discussions on port corridors, and the need for change in the vision and strategic direction of the state.

This chapter is structured in three parts. First, we will begin by analysing the challenges of supply chain management and show how this issue, in the current context, has an impact on global value chains, which we will then go on to define. Second, we will outline the potential transformations within these global value chains that are emerging, and at an increasingly rapid pace amid the current period of crisis and instability, as a result of the Chinese BRI strategy. Finally, we will examine the vision of port corridors in this new context of globalization. We will discuss how this vision proposes to address challenges surrounding the economic attractiveness of territories, a key factor in the success of reindustrialization projects, and secure supply chain management and, more broadly, national sovereignty.

From supply chains to global value chains

The recent crises are therefore having an impact on the flow management of companies, leading them to rethink about their supply chain, as we will begin by illustrating. These changes, in turn, have significant impacts on global value chains.

Business and supply chain performance

Although the precise definition and, above all, the scope of supply chain management are still subjects of debate among academics and practitioners, the Council of

Supply Chain Management Professionals (CSCMP)'s definition, adapted by Camman et al. (2017) is widely accepted:

> Supply chain management encompasses the planning and management of all activities related to supplier research and procurement, processing, logistics and all customer relations activities. It also includes coordination and collaboration between chain partners, who may be suppliers, intermediaries, logistics service providers and customers. In essence, supply chain management thus integrates the management of supply and demand in and between companies.
>
> (p. 243)

Supply chain management is therefore based on the idea that intra- (within company functions) and inter- (between companies) organizational decompartmentalization is crucial for creating value. Performance management therefore relies on dashboards that measure the costs of the various constituent activities, the overall level of service, and lead time, which in return affect cash flow (cash-to-cash cycle), response times, and, finally, flexibility. These recent crises have not changed these performance indicators as such, but they have shaped the choices made for each of them.

Since the financial crisis of 2008, companies have favoured asset-free or asset-light models to improve their balance sheet structure. To this end, they have continued to outsource activities that are increasingly important to their business. This outsourcing has often been accompanied by the relocation of these activities through distant sourcing (Asia and China in particular) to benefit from attractive purchase/production costs. While this strategy has improved the balance sheet of companies (lower fixed assets and therefore improved working capital) and reduced costs, it requires both low transport costs and a tight flow to avoid stock-outs due to poor market anticipation. The investments made over the last 20 years in major ports and maritime transport have made it possible to guarantee this continuity of flows by controlling the associated costs and quality of service.

As mentioned in the introduction to this chapter, the COVID-19 health crisis and the war in Ukraine initially caused major supply difficulties for companies. As the pandemic progressed and Chinese companies were forced to shut down, Western companies had to contend not only with supply difficulties due to the lack of production but also with a significant increase in purchasing costs. In addition, when economic activity did pick up again, impacts were felt across the entire transport chain. Dislocations in supply availability led to demand shortages, an imbalance that led to freight rate increases and container shortages. The historic surge in freight rates translated to a significant increase in transport costs coupled with a decline in service levels. Overall lead times have increased (duration of port operations on departure and arrival plus transit time), leaving companies with limited visibility and reduced levels of responsiveness. Rethinking about flow management methods and inventory levels not only impacts supply chain operations but also raises questions about the overall structure of the supply chain. Against the backdrop of the sudden rise of the "China-plus-one" strategy (having a backup supplier located outside of China), it is the localization of supplies and, therefore, the associated global value chains that are generally under scrutiny.

Global value chains

The notion of global value chains is a key part of the global chain analysis framework proposed by Jennifer Bair (2005). The advent of the term "global value chain" came about in three stages (Balambo et al., 2014). The first stage is rooted in the historical perspective of the world-systems theory, based on Braudel's "world-economy" concept, which places certain countries at the centre of global activity and others at the periphery. Hopkins and Wallerstein (1982), who first coined the term "commodity chain," distinguished between world-empires such as China, which does not tolerate diversity, and the world-economy of Western capitalism. The second stage corresponds to the work of Gereffi and Korzeniewicz (1994), who build on the notion of the commodity chain, defined by Hopkins and Wallerstein as "a network of labor and production processes whose end result is a finished commodity" (1986, p. 159) and propose that of a global commodity chain. These chains are characterized by several dimensions, including a structure that describes the transformation process of raw materials, a territorial aspect, a socio-institutional context that describes the rules governing it, and a governance structure that helps distinguish between producer-led and buyer-led chains. Finally, the third and final stage of this term's emergence corresponds to the desire to break with criticisms related to the term commodity (considered reductive) and to governance logics. Gereffi et al. (2005) proposed the term "global value chain" as an alternative to "supply chain" based on organizational economics of companies. They also identified five types of governance depending on the complexity of transactions, the codifiable nature of information, and the capacity of suppliers.

In line with Bair's definition (2005), we believe that the current concept of global value chains, as defined, focuses more on the hybridization of organizational forms and moves away from the original world-systems objective. Nevertheless, we still believe that the term "global value chain" accurately captures a specific reality. Based on the flows of world trade, materials, and goods, we can distinguish the various "routes" that make up this network. These routes link states and companies, and the activities carried out to produce a good, from conception to final use or beyond, do not concern a single value chain, as defined by Porter (1985), but instead involve a multitude of supply chains. These global value chains, which form the basis of their framework, not only influence the strategies of companies, in terms of their respective supply chains, but also may contribute, particularly in the case of multinational companies, towards structuring their business model and activities. States also play an important role here, as they attempt to position themselves within these chains. Moreover, depending on their economic and political influence, as well as their competitive advantage, these states can shape the configuration of these chains to capture more value, as Porter described (ibid.).

This is particularly the case for China, which helped to structure global value chains at the beginning of the twenty-first century following its accession to the World Trade Organization in 2001. Indeed, in order to become the "world's factory" and take advantage of the strategic outsourcing choices made by companies, China has invested massively in its seaports to ensure connectivity with markets around the world. With the gradual establishment of industrial facilities towards the west of the country, China was able to build up a network of transport infrastructure all along its port corridors (river ports, railways, roads, etc.) which in turn enabled it to maintain a price–time ratio that is attractive to Western companies. As mentioned before, the onset of the COVID-19 crisis has cast doubt on this method of structuring global value chains, but the consequences should also be analysed in the light of changes in Chinese strategy.

From China's strategy to the health crisis: towards a new globalization

The health crisis and the war in Ukraine have raised concerns about the strategic choices of companies regarding their outsourcing and distant sourcing policies. Therefore, it is necessary to examine the potential impacts on global value chains in the context of the Chinese strategy implemented by Xi Jinping in the mid-2010s (2.1).

The Belt and Road Initiative

On 7 September 2013, in a speech at Nazarbayev University in Kazakhstan, Chinese President Xi Jinping announced his intention to create a corridor from the Pacific to the Baltic, linking East Asia, West Asia, and South Asia. This strategy, initially called "One Belt One Road" before being rechristened the "Belt and Road Initiative" in 2017 as it grew in scope, is one of the largest infrastructure projects ever conceived and will require a considerable amount of resources (more than $1 trillion) and a 30-year timeframe before reaching completion. The objective, initially stated by the Chinese authorities, is not only to secure trade routes for companies (raw materials, energy, etc.) and the Chinese population (foodstuffs, etc.) but also to make connections with target markets more reliable and optimized and thereby help China stay a step ahead in terms of costs and time of freight transport.

The envisioned corridor comprises both land and sea routes connecting China to the countries where it sources and markets its products. Most of the sea routes mentioned form the foundation of the global value chains that have emerged since China's entry into the world trade scene in 2001. However, these routes are expanding towards Africa and South America and are destined for the world's leading ports or port facilities in which China has decided to invest to help resolve material supply issues in their respective hinterlands. For land routes, six corridors are envisaged. Without going into detail here, it is worth noting how many of these routes are linked to ports, whether along the Isthmus of Kra, the Bay of Bengal, the Arabian

Sea, or the Persian Gulf. Even the central corridor via Kazakhstan offers maritime alternatives via the Caspian and Black Seas. As it stands, only the corridor via Russia is exclusively land-based. These comprehensive networks of trade routes, with ports as entry and exit points, are envisioned by China to become the global value chains of tomorrow (Amighini, 2017).

To make this strategy a reality, that is to make these new routes operational, China will need to implement a three-fold approach, corresponding to the three levels of a network economy. The first concerns infrastructure (ports, roads, railways, and so on, as well as necessary energy sources). This first stage is currently under intense scrutiny due to its high visibility and the financial loans provided by China, which come with the potential risk of dependency for the signatory countries. The second stage concerns what is generally referred to as "infostructures," that is the concession to operate these infrastructures and the conditions for the user companies. Finally, the third stage relates to the associated services that provide added value to the companies involved, as well as establish industrial activities along these corridors. This element, a decisive part of the Chinese strategy, is often overlooked.

Indeed, it is important to reiterate the fundamental strategic principles that underlie the envisioned connectivity of the BRI. While the issues of supply and distribution to target markets remain central to this approach, they form part of a broader policy of promoting the "tertiarization" and "greening" of the Chinese economy. In concrete terms, this means that the Chinese government is developing an associated industrial and logistics strategy. The Chinese government's intention is to outsource certain industrial activities, currently carried out in China, to new centres located along the corridors mentioned. To facilitate these relocations and maintain the link between China and its emerging centres and, in turn, secure the supply of finished products for the Chinese market, a sound logistics strategy is crucial. Therefore, the ways in which the crises mentioned before unfold could determine the success of the Chinese strategy.

COVID-19 and the new globalization

By raising questions about the structuring and management of their supply chains, the health and Ukrainian crises are leading companies to review their business models. As previously mentioned, this entails identifying alternative avenues to reduce the reliance on Chinese suppliers, whose production hazards (confinement) or transport hazards (port congestion and high freight rates for maritime transport) have penalized Western companies. Here, the question of reindustrialization arises. However, considering the significant investments required from companies, the State, and the local authorities to facilitate the process, this is a medium- and long-term undertaking. This is particularly true in a challenging economic climate, with many companies grappling with difficult post-pandemic financial situations. For the moment, not wanting to drastically alter the direction of their business models (reintegration of activities remains marginal), companies are therefore favouring "nearshoring" solutions, which involves relocating purchasing and subcontracting to nearby countries. However, such a shift may have implications for existing global value chains already being reshaped by the Chinese strategy, which offers new possibilities for "nearshoring."

At first glance, this shift in corporate strategic choices could therefore pose a threat to Chinese companies and to the Chinese economy as a whole, as it will lead to a drop in exports, and therefore a slowdown of economic growth. Still, the objectives of the BRI may provide a different perspective. Given China's desire to move towards a "greener" and more "service-based" economy, and to relocate some of its domestic industrial activities overseas (particularly those in high-density coastal areas), it is possible to envision a convergence of interests. Indeed, Chinese companies that currently operate in China as suppliers to Western companies may decide to relocate their industrial activities to countries closer to their customer base. Chinese companies, which are currently perceived as sources of vulnerability in the existing supply and global value chains, could therefore serve as a solution by relocating their industrial activities, in line with the government's objectives. This, in turn, could contribute towards the development of new routes under Chinese dominance (Sarker et al., 2018; Blanchard & Flint, 2017).

The BRI corridors may therefore facilitate the emergence of new global value chains, characterized by a gradual shift from "made in China" to "made by the Chinese." However, as demonstrated by the ongoing conflict in Ukraine, geopolitical stakes remain high, and the reality of a polarization of industrial activities remains uncertain. In the event that land routes pass through Russia, the Ukrainian conflict could disrupt the balance of power, sidelining the Russian ally from the global value chains it had set its sights on (Gabuev, 2016). Likewise, economic and political tensions between China and the United States threaten to jeopardize the establishment of these new industrial centres. Geopolitical factors, along with their extensions in terms of facilitating customs measures, will be crucial in determining the success of the Chinese strategy, as well as the development of new global trade routes and the polarization of industrial activities in line with the expectations of stakeholder companies. In addition, environmental fiscal measures, such as carbon tax for example, beyond their primary goal of fostering sustainable development, can be employed as a complement to conventional customs barriers.

Beyond the realms of these geopolitical complexities, the structuring of these emerging global value chains demands a dynamic response to the requirements of the companies driving them. Indeed, to ensure effective value chain creation, industrial and logistics/transport activities must demonstrate reliability, as well as responsiveness in the face of the increasingly volatile nature of world markets. Cost constraints continue to be a significant factor in the decision-making process, particularly as inflation rears its head. However, the focus has shifted from a rather narrow outlook (purchasing costs) to a broader perspective (supply chain costs). The corridor-based approach proposed in the Chinese strategy therefore illustrates the need to reimagine the nature of world trade routes as networks that connect ports not only to one another but also to industrial clusters, which depend on ports as entry and/or exit points.

Port corridors: the cornerstone of national competitiveness

Reflections on port corridors are nothing new, and their theoretical underpinnings are not the focus of the analysis in this chapter. Nevertheless, the Chinese strategy, as a world-scale project aimed at structuring new global value chains, prompts us to re-examine the direction and implementation of these corridors in light of the objectives mentioned before, of securing supply chains and national sovereignty, as well as the means necessary to achieve said goals. The design and development of these corridors hinge, as the Chinese project shows, on the integration of various public policies. To guide and synchronize the efforts of the various public and private stakeholders involved, a strong vision and a set of clearly defined objectives are key. This is especially true for transport and logistics corridors, which serve as catalysts for the economic development of corridors, as well as ports, the bridgeheads of these supply chains, serving as strategic entry and exit points for goods and materials.

Aligning corridor strategies with business and government objectives

The concept of corridors, originating from geography, comprises three key dimensions: the physical territory, transport infrastructure, and transport and logistics services (Notteboom, 2012). In addition, we can also consider corridors from a more managerial and, above all, political lens, particularly in terms of the involvement of public and private actors to ensure alignment with land-use planning (Debrie & Comtois, 2010). Corridors can therefore be conceptualized in various ways: as business ecosystems, clusters, territorialized networks of organizations, meta-organizations, collective strategies, and so on. Despite these various definitions, governance remains the core element of corridor-based thinking.

There has long been confusion surrounding the exact definition of this term, a testament to the diversity of possible corridor configurations, as well as the challenges faced during the various decision-making and development phases (De Vries & Priemus, 2003). Furthermore, this semantic confusion underscores the significance of the State(s)'s strategic direction, and therefore of the objectives assigned to these corridors. Not only the Chinese strategy but also the strategies of nations such as Morocco, for example, clearly show that it is no longer merely a question of optimizing connections between modes to reduce overall transport costs and improve fluidity (transport corridors). Nor is it simply a matter of connecting major metropoles to national and continental entry and exit points (ports in particular). Above all, these corridors aim to restructure the national territory by offering national or international companies (such as those engaged in nearshoring in Morocco) new opportunities to organize and optimize their supply chains. They do so by supporting the development of so-called emerging economic areas, whose attractiveness is improved by greater connectivity to global networks. This can be achieved on a national scale, as is the case with Morocco, and on an international scale, as we have seen with the Chinese project. The real challenge, therefore, lies in facilitating the integration and economic development from a global perspective

(Vickerman, 2002), despite the difference in objectives and scope between these two projects.

This objective goes beyond the mere structuring of transport and logistics corridors and raises doubts about the effectiveness of the "economic corridors" promoted by the Asian Development Bank. It also emphasizes the need for improved coordination between public policies that contribute to the development of the resources and skills required by companies, such as logistical and industrial land, human resources, transport and logistics services, digital equipment, taxation, and so on. These elements are essential for maintaining and enhancing the performance of their logistics chains and, in turn, the competitiveness of the territories connected by them. The task at hand is therefore not only to structure an effective and efficient transport network connecting ports to major cities in a linear fashion but also to align its design with a regional planning policy linked to an industrial policy founded on an understanding of the supply chain strategies of companies and their transformation. With the crises and the manifold tensions that they generate, the performance and security of supply chains are becoming a primary concern for States and companies alike. Faced with these shared concerns, governments have been forced to broaden their vision and, in their wake, that of all the major players in these economic corridors. Transport and logistics corridors act as key catalysts for maritime development and optimization. The vision of ports, therefore, as major vectors for the integration and economic competitiveness of companies and territories, is central to this development.

Port corridors: the building blocks of thriving economic networks

The place and role of ports in the design and development of corridors depend on their functionality (ports can serve a solely transport-, logistics-, or trade-oriented purpose, or they can combine all three to create a wider economic-oriented approach). The functionality of ports also partly determines the scope of their geographical reach, which in turn influences the focus of their actions. Derived from development economics and reflecting the logic implemented by China in collaboration with the countries it links through the BRI project, economic corridors are defined as:

> [A] connected series of clusters through an efficient infrastructure and a set of rules linking economic, social, and cultural communities embedded in these clusters. For policy makers, an economic corridor is a set of coordinated actions that ensure a critical mass of investments with the ability to transform the territory through physical connectivity (transport infrastructure), trade facilitation and spatial development.
>
> (Aggarwal, 2020, p. 6)

Port corridors and ports as gateways (as described by Rodrigue, 2007) clearly play a crucial role in the organization and competitiveness of economic corridors. In developed economies, since the reform of the early 2000s, we have witnessed a shift in the mission of ports to better serve this purpose. While delegating handling operations to private operators, this reform emphasizes – beyond the fundamental missions of port authorities including the maintenance and development of maritime access, and the preservation of natural spaces – those of planning, development, and promotion of the port sector. The reform seeks not only to improve port connectivity through land services (especially large-scale modes such as river or rail transport) but also to develop logistic and industrial zones associated with its core business activities. The primary objective of this reform is therefore to effectively meet the needs of port users, mainly shipping companies, logistics service providers, and, ultimately, shippers, whether industrial or distributors. In this regard, the goal is to optimize cost, time, and quality of port passages, as well as to promote, at their level, available land and to collaborate with other actors (especially logistics service providers) to develop a service offer in line with the supply chain strategies in place. However, to achieve this objective, the actions taken will need to extend beyond the boundaries of the port. For example ports must enhance the structuring of networks linking industrial centres to facilitate the transportation of import and export flows related to consumption and, more broadly, all exchanges generated by the fragmentation of supply chains (outsourcing, subcontracting, etc.).

To truly enhance the performance of companies' supply chains and, in turn, the competitiveness of a given territory, the design and development of port corridors must consider the impact of global events and trends on corporate strategies. These port corridors are therefore seen as gateways, serving as crucial "interfaces" within and between the global value chains that shape trade worldwide. For instance the strategic positioning of China in the port of Piraeus, which is directly linked to the Trans-European Transport Network (TEN-T) corridors (a series of nine transportation corridors that are intended to improve the movement of goods, services, and people within the EU), is a testament to this approach, as does the structuring of the Moroccan logistics network linking the industrial and logistics centres to the ports of Tangiers and Casablanca. In addition to optimizing lead times and fluidity through transport and logistics connections, these initiatives also include the promotion of industrial sites and value-added logistics services to cater to the specific needs of companies, often to support the competitiveness of specific industries, such as the agricultural or automotive sectors. At the regional level, the focus is on organizing the hinterland, which includes the development of industrial port areas in terms of their location and the services they provide. Investments can also be extraterritorial to create hubs that enhance the connection between ports and existing industrial and logistics areas – or to support the establishment of new facilities – as well as the consumption areas of the respective countries.

Nonetheless, there is not always scope to develop these approaches due to various financial or strategic reasons. For instance conflicting objectives set by the State may cause actors such as ports to prioritize certain missions at the expense of their core business activities. As a result, for successful corridor development and alignment with industrial policy to be possible, the State must fully consider the strategic challenges of logistics and transport at the national level.

Conclusion

Crises, whether health, geopolitical, or climatic, prompt companies to question the configuration of their supply chains and the management of their flows. Balancing risk factors such as disruptions and price increases is paramount, and companies must work towards securing their supply chains while maintaining their agility. As a result, we are witnessing a shift in corporate purchasing, supply, and industrial subcontracting strategies. These changes, in turn, are having an impact on established global value chains, such as the new corridors initiated by China's BRI project. This project, of unprecedented scope, underscores the pivotal role of logistics–port corridors in world trade.

In this context, then, ports are one of the mainstays of supply chain development, which leads us to consider their performance through a different lens. While the cost, quality, and fluidity of port passage are still vital to meet the expectations of traditional clientele (shipping companies and freight forwarders), the connectivity of ports through maritime and land corridors – structuring their foreland and hinterland, as well as linking them to global value chains – has become increasingly crucial for manufacturers and distributors in streamlining and securing their supply chains. By offering these companies the possibility to form part of these global value chains, ports take on a key role in their strategies in terms of new supply and subcontracting opportunities, as well as commercial development on new markets. Moreover, ports contribute significantly to enhancing the attractiveness of territories by contributing to the achievement of industrialization or reindustrialization objectives that many states aim to accomplish.

Knowledge of how companies structure and transform their supply chains, along with the evolution of global value chains, is therefore at the heart of effective port strategy development and the design of logistics–port corridors. This understanding helps inform the promotion of connections with major corridors, their industrial hubs, and consumer markets. It also helps identify the necessary skills and resources to meet the needs of companies, whether in industrial port areas, on a national level, and even beyond (transport infrastructure and services, industrial or logistic land, added value services, etc.).

The structuring of these new trade corridors clearly requires more than just the involvement of ports, logistics, and transport companies: it requires proactive state-level policies and the alignment of public policies with clear, long-term objectives to guide the strategies of the public and private entities involved. Beyond their design and development, the key lies in the effective governance of these corridors. For this, further interdisciplinary research will be needed in the future.

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8 The Seine Valley Axis

A controversial part of the Trans-European Transport Network

Antoine Beyer

Introduction

This chapter seeks to shed light on the varying interpretations and territorial constructions of the term "Seine Valley": from its national representation (widely referred to as the "Seine Axis") to its inclusion in the system of European corridors, in particular the Atlantic corridor. Although they may appear to overlap, the Seine Axis and the Atlantic corridor differ considerably in terms of means and objectives. This chapter will therefore attempt to understand these differences and whether recent developments could enable a potential convergence that would reinforce both objectives.

The first part of this chapter will provide an overview of the events that have shaped the development of the Seine Axis over time, as well as its positioning within European and national contexts. The second part will situate the Seine Axis within the construction of European priority corridors, highlighting the underlying points of divergence between both the Seine Axis and the Atlantic corridor. The third part of this chapter will examine the current factors of Europeanization at work in the Seine Axis and identify the elements that need to be reinforced in the context of the revision of the Trans-European Transport Network (TEN-T).

The research methodology used for this study is derived from the political framework of multilevel governance analysis (Marks, 1993; Delcourt et al., 2007; Poupeau, 2017). This approach seeks to identify the strategies and representations that shape policymaking at a national (governmental and regional) and European scale, considering both direct and indirect influences across various levels of decision-making. This analysis draws on a wide range of resources, including European texts, academic studies, projects, and financial funding surveys (European Union, 2020; CEF Transport Projects, 2021; Infrastructures de transport de l'UE, 2020; CEF Support to Atlantic Corridor, 2020; Turró, 1999). This information has been supplemented by interviews with managers operating at both regional (Voies navigables de France [VNF] [Navigable Waters of France]; Haropa) and national levels (Interministerial Delegation for the Development of the Seine Valley) as well as European officials (see list given later in the chapter), in order to provide a more comprehensive outlook.

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The Seine Axis: Uncertain European outlooks

Port 2000: a European repositioning driven by a focus on container traffic

Following the shift to container traffic, the Seine Axis has emerged as a significant player on the European maritime scene. Aware that it was lagging behind in the containerization race, France invested in two major development projects: Port 2000 in Le Havre and Fos XLL in Marseille-Fos. Port 2000, a specialized port protected by a six-km-long dike, reclaimed from the Seine estuary, offers considerable scope for the development of container traffic. Indeed, it is thought that in the coming years, with the opening of 12 berths and access to large container ships with a draught of 14.5–21 m, throughput could reach six million TEUs. This potential has helped to level the playing field and has reinstated the port of Le Havre as a key actor in the Northern Range. This has, in turn, led to the massification of flows and the extension of the Seine Axis' hinterland, supported by the strong development of pre- and post-carriage transport, as stated in a report by the Comité interministériel d'aménagement et de développement du territoire (CIADT) (Interministerial Committee for Physical Planning and Development) in 2003.

In addition to port facilities, improving railway capacity was also a top priority. The objective was to gain a strong foothold in eastern France markets, which have traditionally favoured facilities in Antwerp and Rotterdam, and eventually expand services to central Europe. To bypass the Paris hub, and the various logistic challenges of its dense traffic and the prioritization of passenger trains, an alternative northern route was proposed. This route would link the Le Havre terminals via Amiens–Valenciennes to connect to the Nord–Lorraine rail artery towards the northeast, potentially extending to the Rhine valley and beyond (interview with Philizot, 2021). While this route has been laid out in principle, the funding necessary for its completion has unfortunately yet to be mobilized (ibid.).

A contradictory landscape: port reforms, devalued rail infrastructure, and the structural weakness of eastbound flows

Europe's ambitious plans for the port of Le Havre have come up against a number of setbacks. First, works on Port 2000 faced delays following major environmental concerns. Indeed, launched in 2000, the facilities did not see completion until 2006, and the large lock that was to provide direct access to the new terminals for river units was abandoned. The port reform of 2008 and the new status of major maritime ports resulted in strike action against the transfer of crane operators and maintenance workers' management to the private sector. Moreover, the rather rushed decision to build the new multimodal platform led to managerial and financial challenges (Cour des comptes, 2018). In addition, the global financial crisis of 2008 also saw a general decline in maritime traffic. Driven by their concentration strategies, leading shipping lines turned their attention to major hubs like Antwerp and Rotterdam. The envisaged massification of Le Havre's hinterland was stymied by insufficient infrastructure, especially in terms of rail transportation, as SNCF Freight (a subsidiary of the French national railway company, the

SNCF) underwent serious challenges following sector liberalization in 2006. Last, the political transition of 2012 was marked by a waning political support for the French port development strategy.

The strong attraction of Paris

Nonetheless, despite initial setbacks, the 2008 reform gradually gained momentum and yielded positive outcomes. The major French sea ports were urged to focus on developing their hinterland connections and did so with considerable success. Le Havre, with its European ambitions, set its sights on recapturing the Parisian market, a profitable development avenue right on its doorstep. This goal began to truly take shape with the "Grand Paris" project, a competition for ideas to structure metropolitan growth and enhance Paris' competitiveness in a globalized arena (Brennetot et al., 2013). With the support of President Sarkozy, Antoine Grumbach & Associates, a renowned planning and landscape architect firm, gained support for a promising development plan along the Seine Valley, which garnered considerable attention (Grumbach, 2009). This led to the establishment of the General Commission for the Seine Valley in 2010, which was replaced by a Ministerial Delegation in 2013. The appointment of Prefect Philizot to head the delegation marked the beginning of an active policy that brought together the stakeholders from various social and political spheres along the Seine Valley (Philizot, 2016). One key development was the creation of Economic Interest Group (EIG) Haropa (a joint venture between the ports of Le Havre, Rouen, and Paris [Ha-Ro-Pa]). Meanwhile, public debate surrounding the Ligne Nouvelle Paris Normandie (LNPN), a high-speed rail line project linking Paris to Normandy, was set in motion. The construction of the Serqueux–Gisors line dedicated to freight rail traffic gained new ground after decades of discussion and was finally completed in 2021. This rail line offers an alternative to the often-saturated Seine Valley services, but instead of bypassing the Paris region, it serves as a feeder line to the region.

European projections: the second objective or a secondary focus?

Looking over the development of this project over the past 15 years, we can observe that the initial objective of opening Le Havre to European connections has gradually given way to a focus on the Seine Axis, underpinned by the belief that Paris is destined to become a globalized metropolis (Attali, 2010). In fact, management is now homing in on an interregional strategy to strengthen its control over the Île-de-France market. Competition with the port of Antwerp is a recurring theme in the strategic representations of French decision-makers, and the logic of creating a defensive stronghold prevails over the uncertain commercial counter-offensive on the Rhine or on the Moselle.

However, Le Havre still has its sights firmly set on Europe. The Weastflows programme (2011–2015), led by the Agence d'urbanisme Le Havre Estuaire de la Seine (AURH) (the Havre Region and Seine Estuary urban planning agency) and supported by Interregional Cooperation Programme (INTERREG) IVB funding, collaborated with various French and European partners to research the transportation supply (demand, flows, infrastructure) of East–West links along the Seine corridor and its geographical extensions. According to its promoters, this project was a way to restore Le Havre's status as a continental gateway, from the maritime links with Ireland to their extensions towards South Germany (interview with Duszynski, 2021). They claimed that this corridor, though incomplete, could alleviate the congestion of the Rhine routes (Beyer, 2019) and the Benelux ports and that the port was more than a mere extension of the Atlantic arc. The Weastflows programme succeeded in putting the Seine corridor back on the map and reaffirming for the first time its central position within the EU landscape beyond traditional national horizons (Figure 8.1). Still, given the state of existing flows, such ambitions seem far from being achieved, underlining the commercial and technical difficulties that Le Havre must overcome to live up to the promises of its favourable geographical position.

Structural contradictions between geostrategic visions and territorial scaling

As national actors face significant challenges in promoting the Seine Axis as a major transportation route, European authorities also appear to be struggling to find a place for the corridor within the structuring of TEN-T corridors.

Is the Seine Axis on the right track?

It seems that the French government has long underestimated the magnitude of the TEN-T issue. When France adopted the map of TEN-T corridors in Tallinn in November 2013, it became apparent that France was inadequately equipped in contrast to other member states (Figure 8.2). Although three corridors cross France, they seem to be underdeveloped and poorly connected, in stark contrast with neighbouring countries such as Spain and Germany. Furthermore, crucial national links such as the Paris–Dijon–Lyon route were not retained, resulting in Paris being a terminus on the North Sea–Mediterranean corridor. The most plausible explanation for this disparity is that rail freight corridors were prioritized when creating the map, resulting in the retention of major freight routes only within an international transit context, particularly towards the Iberian Peninsula.

The development of the Seine Axis is therefore somewhat thwarted by its connection to the Atlantic corridor, which mainly prioritizes continental and rail-based transport in a southwest–northeast configuration. The corridor's linear development places the centre of gravity and attention far to the south, especially since the link to Germany is primarily focused on high-speed and passenger transport. Moreover, French operators are reluctant to saturate their rail network with Spanish freight in transit, which in turn weakens the overall dynamic of the corridor. These diverging approaches are reflected in the reports of the European coordinator, Carlos Secchi, who emphasizes the importance of Pyrenean rail connections. In addition, the marginalization of river transport further diminishes the status of

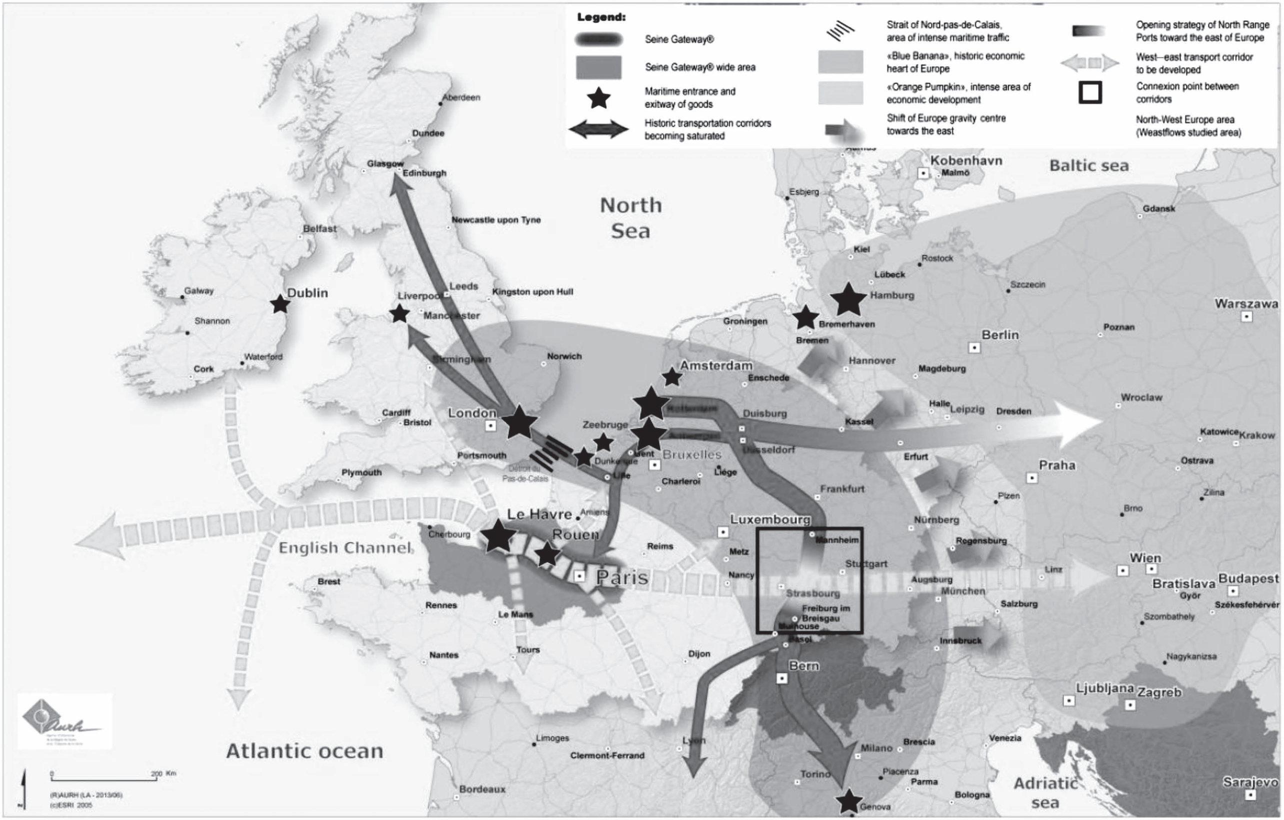

Figure 8.1 Geostrategic vision of the Seine Gateway as an alternative East–West route on a European scale.

Source: AURH 2015.

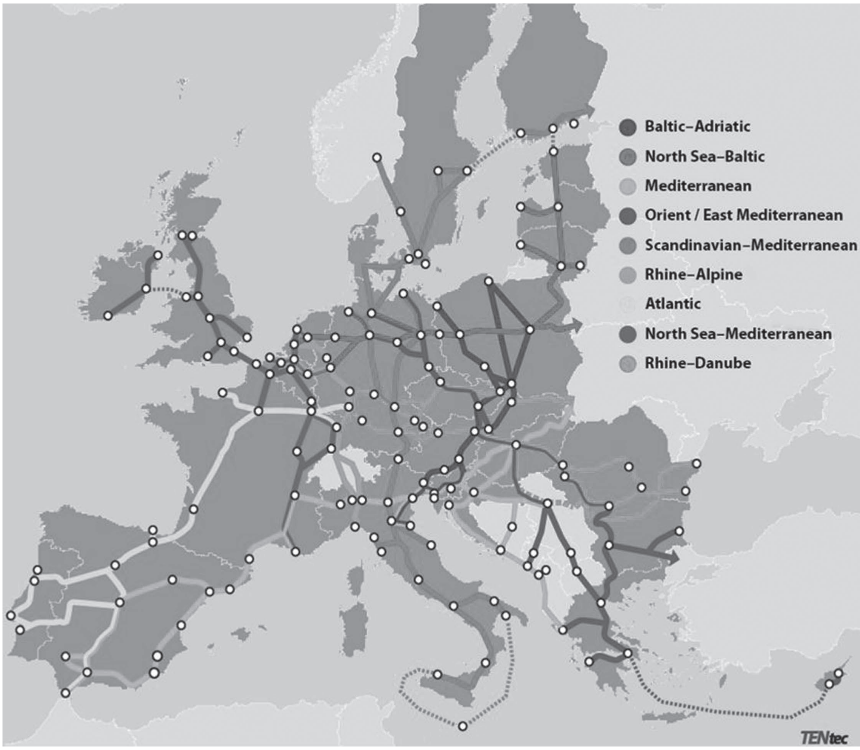

Figure 8.2 The nine European network corridors (EU Regulation, 2013).

the Seine Axis. It is therefore no coincidence that the European coordinator of the corridor and the French Delegate for Spatial Planning of the Seine Valley have yet to meet in person (interview with Philizot, 2022).

The interregional isolation of the Seine Axis

While it has seen considerable development over recent years, and largely independently from wider European networks, the Seine Axis remains relatively isolated from the rest of France. In the direct wake of the 2008 port reform, public policies have launched a multimodal approach centred around three major ports (Haropa, Marseille-Fos, and Dunkirk) as the main maritime entry points. This resulting spatial cluster supported by the state – comprising the Seine Axis, Medlink, and NorLink – has become the main focus of national logistics development policies, leaving the rest of the territory out of the picture. The Seine Axis' poor connectivity with the remaining network is therefore felt not only on the European scale, but it also raises concerns about its ability to connect with other large neighbouring regions. It would therefore appear that the development of the Seine Axis is driven by endogenous development, especially along the short corridor that stretches from Le Havre to Paris, particularly downstream from the French capital in the west.

Indeed, the outlet of the Seine Valley is highly constrained in terms of freight capacity. To the west, the two road bypasses of the A86[1] and the Francilienne – a highway in the Île-de-France region – remain incomplete (Figure 8.3). The Serqueux–Gisors rail line and the track serving the river port of Limay both terminate at Conflans due to restricted traffic on the Mantes–Argenteuil track, preventing them from connecting directly to the Grande Ceinture, a freight-only railway ring road. River crossings of Paris are limited by the bridges air draft, and freight flows are generally subject to the intensity of passenger flows. This spatial configuration hampers access to industrial and logistics zones, which are mainly located to the north and the east of the region and poorly connected to waterways. Plans have been made for a bypass of the Île-de-France region, which are close to seeing completion for road transport – albeit at the cost of a substantial detour. However, there is a significant delay in upgrading the rail infrastructure on the periphery of the Paris Basin, which remains unelectrified unlike the heavily trafficked radial routes that converge towards the Parisian node.

Diverging regional interests: an ongoing power struggle between the Seine and the Scheldt

As the Seine Axis was conceived as a regional and, above all, defensive initiative, it is easy to understand the reservations and even hostility of major public and private stakeholders towards the construction of the Seine–Nord Canal. Indeed, this new infrastructure, by connecting the Seine and Scheldt basins on a large gauge basis, may open the door to competition from rival ports in the Northern Range. On the other hand, the project has received strong support from the Hauts-de-France region, set to reap various benefits from this new infrastructural development: direct economic impact from construction activities, creation of intermodal platforms likely to revitalize abandoned industrial sites, lower transport costs for agriculture and related processing activities, and strengthening of the region's role as a logistic hub between the major markets of Île-de-France and the Benelux countries. Once the Seine–Nord project was confirmed and received the necessary political and financial backing from the European Commission, which sees it as a key element of its interconnection policy, the need to accelerate the integration and transformation of the Seine Axis became all the more urgent.

How can the Seine Axis gain a European dimension?

Connecting the eastern and western parts of the Île-de-France logistics network

In the region of Île-de-France, transport and warehousing activities have flourished along the eastern crescent running from north to southeast, mirroring the productive and industrial areas that once stood in their place. The predominant road infrastructures, specifically the A86 and the Francilienne, have caused a concentration of logistics activities along their main routes and intersections with bypasses. As

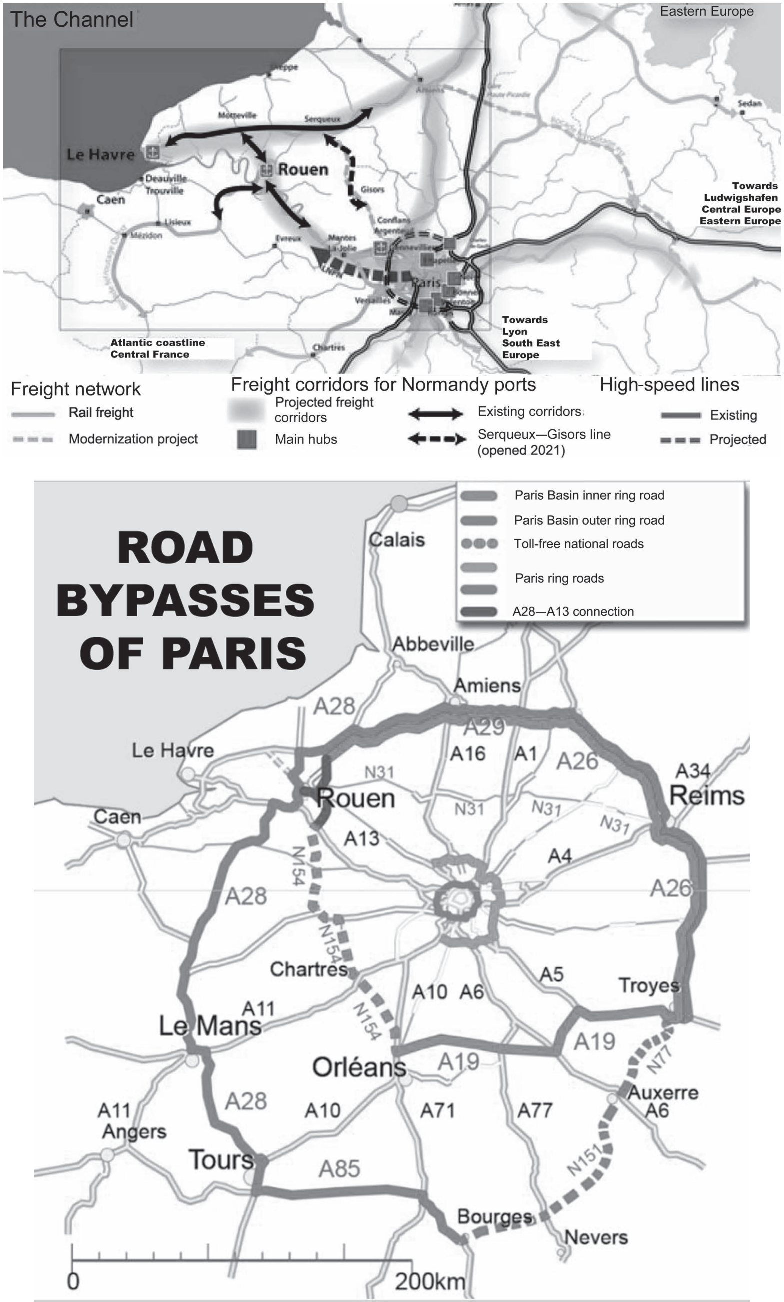

Figure 8.3 Incomplete bypass infrastructures around the Île-de-France region (a) by rail (and (b) by road.

Source: RFF and Study of the Contournement Est de Rouen [eastern Rouen bypass].

a result, the expansion of these activities has mainly followed this geographical pattern towards the outskirts of the region. Conversely, the western part of Paris (Hauts de Seine, Yvelines), characterized by a lower industrial focus and higher real estate costs, suffers from an incomplete road network, as detailed earlier. This two-fold freight constraint is a real hindrance for goods traffic from Le Havre, because it is necessary to cross the dense urban area to reach the main logistic areas. Public planners seek to rebalance the platforms coverage in the west of Île-de-France, particularly along the Seine Valley, which has seen a significant increase in wastelands due to deindustrialization, especially in the automotive sector. In the east of Île-de-France, on the other hand, where road and rail continuity is secured, improving transit function will enhance the overall attractiveness of the region. These major spatial contrasts therefore hammer home the idea that Île-de-France is the terminus of the Seine Axis. However, promoting territorial rebalancing of logistics without ensuring connectivity could lead to a regional logistic divide. To avoid this, local actors must secure the infrastructural connection between the Seine Valley in the northwest of France and the logistics crescent in the east, thereby completing the bypass system and opening up the axis to potential European destinations. Unfortunately, new major infrastructural developments come up against fierce opposition from local residents, particularly in the affluent Western suburbs, which has hindered progress in this direction for decades. As a result, the high population density in Paris remains a Gordian knot, and connections between the Seine Axis and the national and European networks continue to prove complex.

Towards Europeanization: financial incentives and procedural frameworks

The position of the stakeholders of the Seine Axis on the European stage goes beyond their mere participation and connections to a European corridor, and it is important to remain wary of any potential influences from the core TEN-T network's map and the suggested connections. Nonetheless, being part of a corridor offers inherent advantages, particularly in terms of access to European funding: up to 50% funding is available for studies, and 20–40% for the works themselves, which can go up to 85% for states receiving aid from the cohesion fund, regardless of any synergies within a predefined corridor. The Seine Axis has already tapped into European funding with the Serqueux–Gisors line receiving €66 million out of €246 million and the Le Havre channel receiving €25 million out of €125 million. In the period between 2014 and 2020, the Seine Axis accounted for 12% of the amounts paid out for development within the Atlantic corridor, and 7.1% of the French subsidies received under the TEN-T (i.e. 37% of the expenses incurred, with the French State covering the remaining 63%) (CEF Support to Atlantic Corridor, 2020). These amounts do not include the renovation of locks on the Seine, which are part of the North Sea–Mediterranean corridor under the Seine–Scheldt project. Although belonging to the European core network does not directly equate to additional traffic, it does bring a priority principle that guides the associated national financing capacity. In this sense, the EU's financial support offers a clear advantage for projects located on TEN-T corridors (interview with Bour, 2021).

In a similar vein, competing for European funding may also bring about indirect advantages, not so much from a technical standpoint, but in terms of the contracting process by urging the European Commission to improve the quality of its reporting procedures. VNF considers Europeanization to be a beneficial approach, since submitting reports on fund usage to the Commission within the given time frame leads to greater procedural transparency and greater efficiency (i.e. faster execution). The more rigorous monitoring of European projects ensures a high rate of execution, which must be reported to the commission. Once established, the procedure fosters industry know-how and competency, which can stand to benefit projects across the board, whether European or not (interview with Lavelle, 2021).

We have also witnessed a shift in the perception of French actors towards the importance of TEN-T, especially for the Seine Axis, as the voices of lobbyists from French community bodies in Brussels gradually grow louder. Haropa, since the establishment of the EIG in 2015, has been the first French port with a permanent representative specializing in European affairs, who is based in Brussels. The Europe team now has four members, including two permanent staff members. Consequently, Haropa is now able to take on responsibilities within representative structures such as the European Sea Ports Organization (ESPO) and European Federation of Inland Ports (EFIP), enabling it to exert greater influence in European debates.

Collaboration among major ports through research programmes also plays a significant role in enhancing European influence. For instance Haropa has the opportunity to collaborate with other European ports, typically considered competitors, within the framework of initiatives such as sMArt Green Ports, Horizon2020, and Horizon Europe, including the MAGPIE (sMArt Green Ports as Integrated Efficient multimodal hubs) and PIONEERS Ports projects, as part of calls for tender (interview with Virciglio, 2022). When several ports share a set of challenges, a seafront approach can be adopted, which offers a competitive advantage for ports in the Northern Range, which can pool their efforts to overcome shared technical problems. These examples serve to illustrate that the Europeanization of the Seine Axis extends beyond mere geographic continuity and coherence as a corridor.

The impact of the 2021 TEN-T revision

The effective implementation of Brexit at the end of January 2020 and the ongoing discussions surrounding the revision of the TEN-T have prompted a review of the network map for the 2021–2028 programme (Figure 8.4). The proposed changes include a stronger integration of ports and the overall expansion of the network. The de facto abolition of the British land bridge has greatly strengthened French Channel ports as a transit point for Irish trade with the continent (interview with Lacey, 2022), reinforcing the vision of the Weastflows project. The shift in routes has also helped strengthen the Seine Axis, which is now covered by two corridors: the Atlantic and the North Sea–Alps (resulting from the merger of the North Sea–Mediterranean and North Sea–Alpine corridors). The waterway as a transport mode has taken centre stage in the re-evaluation of the Seine Axis' role and its

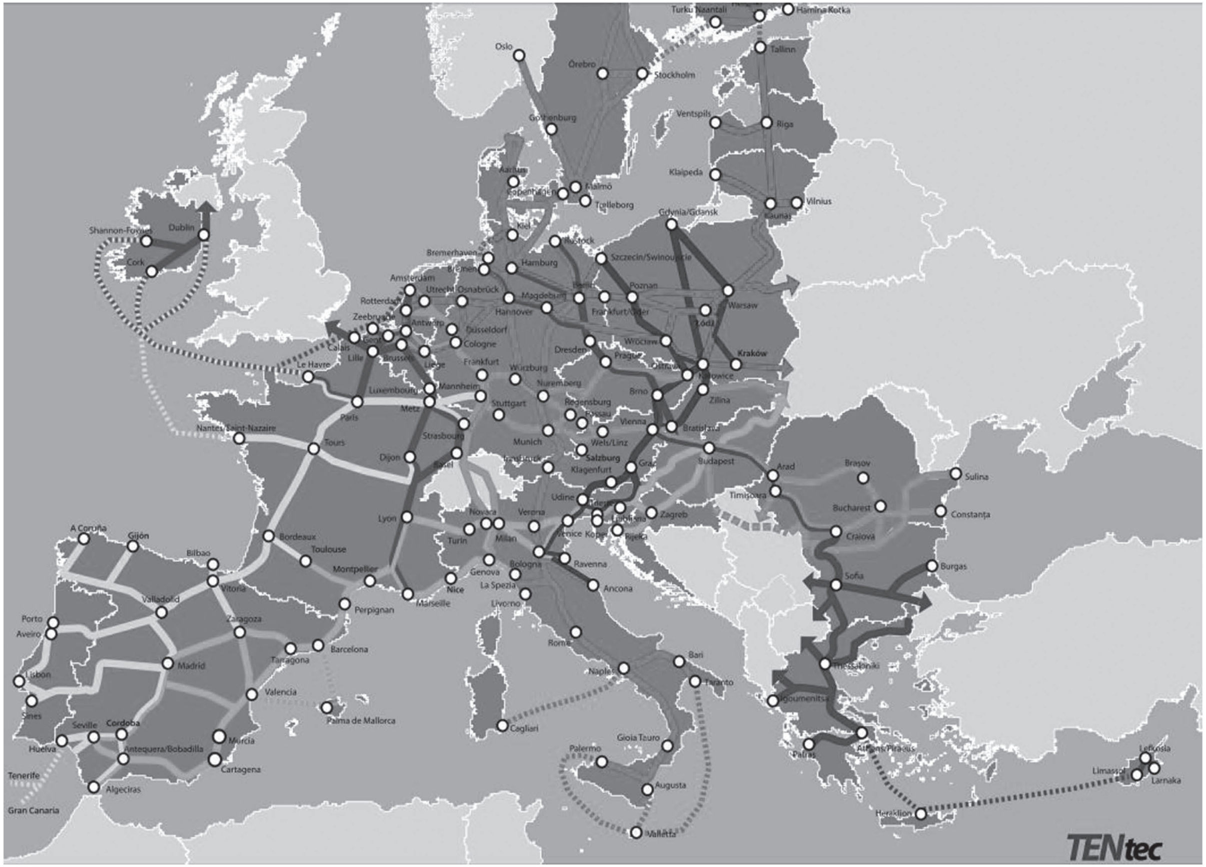

Figure 8.4 The nine core network corridors following the 2021 revision.

Source: TENtec Interactive Map Viewer. 2022.

future prospects, including the upcoming construction of the Seine–Nord canal. The promotion of inland waterways contrasts with that of railway, as it fosters a wider interregional system of cooperation.

The Seine corridor has therefore emerged as a reliable axis within the European Transport Network, with the Le Havre and Paris nodes playing critical roles. The Paris node, for instance, has established itself as a major hub in the European arena, bolstered by the Lyon–Dijon link and by the Seine–Scheldt inter-basin continuity, which no longer leads to a dead end. However, to realize its full potential, the Seine Axis must extend its reach beyond its conventional sphere of influence. To do this, it must address the challenges of crossing or bypassing the Paris metropolitan area.

The vision of the Seine Axis as a reliable transport network, not only within France itself but also on a European scale, is being increasingly reinforced by port operators themselves. For instance Haropa's successive acquisition of a stake in the management of Rhine terminals in Alsace via Terminaux de Paris, including Lauterbourg in 2020 (R3flex) and in Ottmarsheim in 2021 (Rhein Ports), is a clear indication of this. The integration of Rhine flows will eventually pave the way for the development of complementary or alternative multimodal services to and from the Seine.

Conclusion: broadening the scope of the Seine Axis corridor

The Seine Axis offers an intriguing case study of the uncertain relationships between planning schemes at national and European levels, marked by a complex interplay of ignorance and potential convergence, and in which port service issues play a central role. Moreover, the geographical mix of urban, metropolitan, and regional areas adds an extra layer of complexity, posing significant challenges for transit traffic.

Initially, the servicing of Le Havre and the launch of Port 2000 were viewed as part of a broader European strategy, aimed at extending its container hinterland as far as central Europe. However, the Greater Paris planning programme has since scaled back the project to a more realistic and practical level, restructuring the project to cater to a more national or even interregional context. For instance the Seine Axis has been assigned the primary function of serving as a maritime gateway for Greater Paris, as well as a development corridor for local industry reinvestment and facilities in energy transition. The question of its connectivity with the European system has received less attention, as priority has been given to positioning Paris as a global and sea-connected metropolis and because it appears that the Seine Valley is not considered a priority area by the TEN-T when it comes to developing transport infrastructure across Europe. This also reflects the overall preference of public and private decision-makers for endogenous interregional development. The controversies surrounding the suitability of the Seine–Scheldt link, or the construction of the Serqueux–Gisors rail freight track, are telling examples of this preference.

The end of 2021 saw a recasting of the TEN-T, prompting a reassessment of priorities in the wake of Brexit-related challenges, such as port transit to Ireland

and the launch of the construction on the Seine–Nord Canal. As a result, the Seine Axis is now attached to two corridors: the Atlantic corridor and the North Sea–Mediterranean corridor. Given the impressive efficiency of this connection, there is renewed discussion of expanding eastward. This could be achieved either by crossing the Paris metropolitan area or by bypassing the Greater Paris Basin, though the latter option remains incomplete, particularly in terms of rail facilities. This would not only open up the Seine Axis to broader European horizons but also allow it to forge stronger ties with neighbouring regions such as Hauts-de-France, Grand Est, and Centre, where inland waterway transport plays a key role.

Note

1 The A86 duplex is technically not accessible to trucks between Versailles and Nanterre, as the height of the tunnel only accommodates cars.

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9 Governing logistics corridors – scope and limitations of inter-territorial coordination

A case study of the Seine Valley

Nathan Gouin and Arnaud Brennetot

Introduction

Logistics corridors pose significant economic and ecological challenges that require coordinated action and cooperation among local stakeholders. For example collaborative efforts between upstream and downstream territories are crucial, particularly with regard to regulating flows and their supporting infrastructures. These concerns may affect the supply chain directly (optimization, multimodality, etc.) or relate to broader issues that arise during logistic operations (preservation of biodiversity, land consumption, etc.). Thus, corridors are a critical scale for strategic planning. Despite the emergence of several inter-territorial projects over the last 15 years, such as soft spaces resembling gateways (Atlantic Gateway, Thames Gateway), results remain incomplete and their progress precarious (Allmendinger et al., 2015). In this chapter, after detailing the issues specific to the governance of logistics corridors, we will focus on the case of the Seine Valley to highlight the scope and limitations of the cooperation mechanisms at play.

As the main artery linking the Paris metropolis to the port of Le Havre, the Seine Valley corridor has long been singled out as a critical development issue for the French territory. Following the launch of a major initiative in 2008 by President Nicolas Sarkozy as part of the Grand Paris project, many local and regional actors have attempted to organize themselves at the interregional scale and put forward numerous projects. Nevertheless, tangible results remain scarce, largely due to a lack of coordination between local actors. Through this case study, we will show that cooperation difficulties can stem from various interrelated institutional, geopolitical, and ideological factors. In the Seine Valley, the main factor in the lack of coordination stems from the hesitancy of the central government, against a backdrop of rampant centralism in which local authorities have limited scope for action.

The governance of logistics corridors

Logistics corridors as strategic spaces

Corridors can be viewed from two angles. On the one hand, corridors can be considered from a functional perspective: they refer to clusters of (multimodal)

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infrastructures, generally linear, around which urbanization, economic development, and transport-related services (logistics) are concentrated (Alix, 2012). On the other hand, corridors can be viewed as institutional spaces aimed at planning the interconnection of a port terminal with its hinterland and promoting the development of the resulting logistics system (Priemus & Zonneveld, 2003; Debrie & Comtois, 2010; Beziat et al., 2014).

The objectives of these planning policies are diverse. Historically, the main focus was on stimulating economic development by improving the connectivity of a region (Trip & Zonneveld, 2003). These development plans were aimed at increasing port traffic and creating added value in the hinterland. Over time, new objectives related to sustainable development were integrated into these planning efforts (Debrie & Comtois, 2010). Corridors were designed to connect territories through larger-scale and greener modes of transport (waterways, rail); to reduce the reliance on road transport; and preserve the quality of ecosystems that are often rich in biodiversity. Moreover, corridors can also serve as a means to rally local actors around a shared goal, particularly when it comes to facilitating dialogue between private and public entities (Beziat et al., 2014). Faced with the increasing demand for flexibility due to the evolution of supply chains, the massification and diversification of transported goods, as well as increased standardization stemming from the rise of containerization, public and private actors stand to benefit greatly from enhanced coordination (Hesse & Rodrigue, 2004).

Looking at corridors from various perspectives, they can be seen as "logistics integration axes" (Rodrigue, 2007) that pave the way for greater fluidity, competitiveness, and multimodality. Depending on state traditions (Loughlin & Peters, 1997), this integration can be top-down, that is initiated and driven by the central state or bottom-up, mobilizing the participation of local and regional actors (Beziat et al., 2014). This latter form of integration is particularly important, but its implementation remains complex.

The multiple dimensions of corridor governance

To govern corridors successfully, cooperation is necessary in various aspects. Because of their vast scale, corridors often extend beyond the administrative boundaries of their integrated territories (Trip & Zonneveld, 2003), calling for inter-territorial cooperation (Perrin, 2012) within the framework of "soft spaces" (Allmendinger & Haughton, 2009; Allmendinger et al., 2015).

Moreover, effective corridor governance requires cooperation between actors operating at different levels, within a dynamic multilevel governance system (Hooghe et al., 2016; Poupeau, 2017). It also requires the support of multiscale institutions such as the European Union, central states (one or more depending on the case), and local authorities. Ultimately, corridor governance involves reconciling actors with varying and, at times, conflicting agendas and resources. For example public actors (government agencies, elected officials, etc.) generally have broader expectations than business leaders, who tend to prioritize freight transport optimization (Beziat et al., 2014). In addition, various business sectors within a given corridor may have divergent interests depending on the type of goods they exchange and produce. Unions, particularly those representing port and rail workers, also play a major role, and their priorities sometimes differ from those of other private stakeholders.

As a result, in many corridors, governance stands as a key issue, even an obstacle, to achieving coordination between stakeholders. For example in the context of the international Randstad–Flanders megacorridor, Romein et al. (2003) observed a lack of multilevel governance, with decisions still being made at the national level when there was a clear need to scale up decision-making procedures. Likewise, in the context of Canada's Asia Pacific Gateway and Corridor project, Debrie & Comtois (2010) noted that although the horizontal integration of the corridor resulted in the rapid merger of the three ports of Vancouver, interest in the project dwindled over time, and interests between the provinces of Quebec and Ontario became increasingly divergent.[1]

The risks of non-cooperation

A lack of coordination between stakeholders in territorial planning can have significant negative consequences. One of the most significant risks is the potential for rivalry between territories for hosting infrastructure such as multimodal platforms, landing quays, and training centres. When managed poorly, failed cooperative efforts can also result in land-use-related conflicts, in particular along riverbanks, where opposing productive, residential, and ecological functions can collide.

Inadequate coordination may also lead to scattered efforts and investments, thereby preventing local actors from tackling important larger-scale issues that require substantial resources, such as the construction of new infrastructure, investment in alternative energy resources, as well as research and development. Furthermore, the compartmentalization of territorial strategies may hinder the development of economies of scale that will allow economic actors to benefit from positive externalities, such as the promotion of new business sectors.

In addition, a lack of inter-territorial coordination means that the challenges of interdependence between the territories forming a given corridor cannot be addressed, particularly with regards to economic development, spatial planning, and environmental preservation. From an economic point of view, it is necessary, for example, to link the downstream gateway (the harbour) with its hinterland, not only for the management of import and export flows but also for a concerted integration of productive sectors.

The absence of integrated planning between dense and non-dense areas can also lead to spatial fragmentation, with activities distributed according to commercial logics of polarization that pit gentrified urban centres against peripheral areas hosting activities with high environmental impact (pollution, land use, etc.). In the end, corridors constitute rich and integrated ecological systems in terms of biodiversity, which require coherence and respect for continuities and ecosystem interdependencies within the river basin.

Given all the reasons outlined earlier, corridor governance is undeniably a crucial issue (Comtois & Debrie, 2010). The poor coordination observed in various corridors hinders the implementation of sustainable development and management policies, as the situation in the Seine Valley in France serves to illustrate. Despite numerous political initiatives since 2008, progress has been slow, a testament to the multiple constraints impacting territorial cooperation at the corridor level.

Territorial cooperation initiatives: the case of the Seine Valley corridor

As early as the Middle Ages, the Seine Valley has served as a major axis for penetration and circulation throughout France and Northwest Europe. It also has the particularity of being home to Paris, a major geopolitical and geo-economic powerhouse (Braudel, 1986). The Seine Valley is divided between two administrative regions (Île-de-France and Normandy) and features a conurbation of three main cities (Paris, Rouen, and Le Havre), which also house three functionally complementary yet institutionally competitive port facilities. Today, the Seine Valley faces a new set of challenges related to the economic and ecological transition.

Despite its long history (Saunier, 2006), the idea of turning the Seine Valley into a strategic axis has sparked renewed interest since 2008 as discussions on the development of Greater Paris came to the fore. Since then, the Seine Valley has been the subject of numerous integration proposals. However, despite the abundance of suggestions and initiatives, progress has been limited to modest achievements.

A territory claimed by a diverse set of stakeholders

Table 9.1 identifies three distinct phases in the mobilization of actors within the Seine Valley. The initial phase (2008–2012) coincides with President N. Sarkozy's term of office, characterized by ambitious plans to promote economic growth by connecting Paris to the sea (Brennetot et al., 2013). A high-speed rail line linking Paris to Normandy was announced for 2017, including a new station in Rouen to be located in a future business district. Plans were also made for major infrastructure projects, such as the development of a major motorway ring road in Rouen; the merger of the ports of Paris, Rouen, and Le Havre; and the construction of a river access route to the main maritime container terminals. In addition to these logistic advancements, the objective was to improve higher education and research facilities; foster industrial innovation; and enhance local attractivity in terms of tourism, services, and quality of life. The cost of these projects was estimated at €18 billion by the General Commissioner for the development of the Seine Valley, Antoine Rufenacht, former mayor of Le Havre and historical figure of the French right.

In 2011, a public debate was held on the Ligne Nouvelle Paris Normandie (LNPN) project, plans for a high-speed rail line linking Paris to Normandy. This was followed by the creation of an Economic Interest Grouping (EIG) called "Haropa" in 2012, intended to unify the commercial offer of the three ports of the Seine Valley – Paris, Rouen, and Le Havre. For the first time, the mayors of the major cities in the Seine Valley (Paris, Rouen, Le Havre, and Caen), together with urban planning agencies and the Chambers of Commerce and Industry, began

Table 9.1 Main phases of mobilization of Seine Axis actors.

Period	*Characteristics*	*Main actors*	*Main objectives*
2008–2012	Wide range of proposals	Various (the architect Antoine Grumbach, the French President Nicolas Sarkozy, the government, Chambers of Commerce, urban planning agencies, and local elected officials)	Geo-economic: improving the competitiveness of Paris and France
2013–2020	Institutionalization of the corridor Partial demobilization of economic actors	Interdepartmental delegation Regions Members of parliament	Sustainable development: reconciling economic growth and balanced regional development
2021 to present	Remobilization following the Haropa port venture	Haropa port Elected officials of major cities Port communities	Ecological transition and decarbonization as factors of attractiveness

holding regular meetings to express their support for the initiatives launched by the central government. In 2012, the central government created a Seine Valley Development Conference to coordinate all stakeholders' efforts.

The period of 2012–2020 gave way to a second phase of the Seine Axis' development, this time marked by a partial reduction in mobilization. Shortly after being elected President of the Republic in 2012, François Hollande disbanded both the Commission and the Conference for the Development of the Seine Valley. In their place, an Interministerial Delegation for the Development of the Seine Valley was created, which was headed by F. Philizot, a member of the prefectural corps. This new delegation has limited resources and lacks the political authority of its predecessor, led by the former minister and mayor A. Rufenacht. This delegation has two main missions: to develop a strategy for 2030 and to draw up a State-Region Interregional Project Contract aimed at initial implementation. Passed in 2015 with a budget of just under €900 million, this interregional contract aims to finance various infrastructure projects, including the modernization of a rail section for freight between the Caux plateau and the Vexin near Paris. Nonetheless, this freight line remains the only significant infrastructure project that has seen completion for the development of the Seine Valley since 2008.

In 2013, the central government announced that the LNPN project would be divided into three phases, with the first phase postponed until 2025, the second until 2030, and the last to an undetermined date. In 2018, the government announced that the various sections of the first two phases were being re-evaluated and pushed back to a date between 2027 and 2037, or beyond, and the timeframe remains unspecified to this day. These successive postponements, accompanied by an increasingly vague timetable, ushered in a progressive demobilization of the actors involved. By 2018, the president of the Normandy Region, H. Morin, openly expressed his doubts about the State's willingness to support the LNPN project. Elected officials of the Île-de-France region, for their part, remain hostile to the idea of hosting the infrastructure required for the passage of the LNPN, especially the construction of a railway bridge at Clichy-sur-Seine. Still, with works being postponed until 2032, their discontent has been somewhat tempered. Norman decision-makers, on the other hand, fear that the State, the SNCF,[2] and elected officials in the Île-de-France region will prioritize suburban connections at the expense of the LNPN, illustrating the diverging interests between the different sections of the valley in terms of rail infrastructure development.

Meanwhile, port cooperation continued, but there were no significant concrete achievements until 2018. The Normandy Region proposed to take over the management of the two major seaports of the Lower Seine (Le Havre and Rouen) but was unsuccessful. The region then reproached the State for having abandoned plans for a new river access to the port of Le Havre and decided to go about the project alone. From 2014 onwards, there was a decline in communication between major cities at the local level, while the cooperative efforts of the Chambers of Commerce and Industry and the urban planning agencies waned. During this period, the economic decline of the Seine estuary increased, out of step with the ambitions stated at the beginning of the project. The governance of the Seine Valley therefore faced significant difficulties that have compromised the achievement of its initial objectives.

Starting in 2021, the development of the Seine Axis has entered a third phase, marked by a remobilization of its various stakeholders. The appointment of E. Philippe, mayor of Le Havre, as Prime Minister (2017–2020), breathed new life into the Haropa merger project, which was eventually achieved in June 2021. Following controversies surrounding the location of the headquarters of the new port institution in Le Havre, the Normandy Region and private companies in the port sector are now criticizing the State for their lack of representation on Haropa's Supervisory Board. This institutional merger has failed to resolve the issue of the broader strategy, particularly in relation to other upcoming projects such as the Seine–Northern Europe canal, which is expected to rival the Seine Valley for the supply of the Île-de-France region. The success of these port synergies across the Seine Valley will hinge on the ability of Haropa's management to effectively coordinate the three territorial divisions of Paris, Rouen, and Le Havre and to move developments forward in a coherent and concerted manner. Since 2021, after being put on hold for several years, there has also been a revival of inter-municipal cooperation between Paris, Rouen, and Le Havre, this time to promote the decarbonization of the Seine Valley. However, this initiative is in direct competition with a similar project under way in the regions of Normandy and Île-de-France.

Coordinating actions has proved challenging, as evidenced by the two-year standstill in negotiations that preceded the renewal of the planning contracts between the central government and French regions, with an agreement finally being reached in October 2022. In the meantime, the Interministerial Delegation for the Development of the Seine Valley has been discreetly preparing to update the state's strategy. On the railway front, disagreements persist among the SNCF (a state-owned company), the Normandy Region, elected officials in Île-de-France, and user associations over issues such as the management of halts and timetables, maintenance of lines and rolling stock, and recurrent failures. Despite the repeated efforts of the various stakeholders, these discussions have not led to any significant improvement in relations, nor has anyone suggested the shortening the timeframe for completion of the LNPN. While the structuring of actors on the scale of the Seine Valley is much more developed than in the other major French corridors such as the Northern Axis and the Mediterranean Rhone–Saine Axis, concrete achievements remain rare. At the same time, there is a continued lack of coordination between the various stakeholders in their initiatives.

Factors explaining the lack of cooperation in the Seine Axis

This failing governance can be viewed through a neo-institutionalist lens, whereby a complex interplay of institutions, interests, and ideas allow for an understanding of political blockages and changes (Hall & Taylor, 1996). From a political standpoint, France is often defined as a "Napoleonic" state, characterizing its unitary, centralized, and technocratic nature (Loughlin & Peters, 1997; Painter & Peters, 2010). Still, the influence of local figures should not be disregarded (Grémion, 1976). Despite the process of decentralization that France has undergone since the 1980s, the organization of political power remains centralized compared to its Western European neighbours (Hooghe et al., 2016). The state is therefore a central actor in territorial development through the legal and financial control it exercises over local authorities. Moreover, the state's involvement is critical as agencies, companies, and public establishments, such as the SNCF or port facilities, play a determining role in the spatial organization of corridors.

In the Seine Valley corridor, this state dominance is particularly strong. Unlike other European harbours such as the ports of Rotterdam or Antwerp, where local governments and economic actors have substantial representation, French ports are administered by the state and managed by senior officials. Business actors, in contrast, merely serve in an advisory capacity in governance. Despite repeated official statements advocating for the development of the Seine Valley over the past decade, the state has not fully assumed its leadership responsibilities by developing a clear strategy with sufficient funding and a management team capable of bridging the divisions and rivalries among local actors. This "wait-and-see attitude" allows the state to avoid committing to significant investments and implementing a multilevel governance that could lead to concrete outcomes.

The state's relative passivity leads us to the second contributing factor: the inability of regional and local authorities to collectively initiate their own development dynamics. Indeed, these authorities face limited regulatory and financial capacities, which prevent them from carrying out large-scale projects. Moreover, the proliferation and fragmentation of local and regional institutions are hardly conducive to cooperation. No local authority has sufficient power to promote bottom-up synergies, except perhaps the Île-de-France region. Given the lack of leadership among local authorities, we are unlikely to see an end to the frequent resurgence of old or emerging geopolitical rivalries, whether between territories vying for infrastructure investments and the installation of new activities or between levels of government competing for more competencies or specific prerogatives.

For several decades now, a key geographical factor has also hindered cooperative efforts. The Seine corridor is divided into two institutional regions: Normandy and Île-de-France. These two regions differ greatly in terms of population (3.3 and 12.3 million inhabitants, respectively), economic power, as well as their dynamics and priorities. Historically, planning in the Paris region has been centred on the Île-de-France area and has tended to neglect interdependencies with the downstream part of the corridor, as shown by the concentration of logistics sites in the eastern part of the region without any links to the megaregion's seafront (Figure 9.1). However, because of their demographic and economic weight, the involvement of Île-de-France stakeholders is essential to the development of the Seine Valley.

Finally, to fully understand the political rifts within the Seine Valley corridor, certain ideological factors must also be taken into account. Although common discourses and objectives can a priori be observed surrounding the development projects of the Seine Axis, when transport and logistics-related projects take shape, deep-seated ideological divisions begin to surface. This often boils down to divisions between two main camps: on the one hand, supporters of a sustainable development strategy that balances economic interests and emerging consideration of socio-environmental issues; and, on the other hand, those who champion a more ecologically driven approach. The socialist mayors of Rouen and Paris, committed to a post-productivist transition, regularly clash with business and right-wing actors on the issue of transport (speed regulation, restriction of the presence of motor vehicles in city centres, opposition to ring road projects). Activities deemed harmful to the environment, such as the construction of port infrastructures or the establishment of logistics warehouses, have also given rise to frontal disagreements between stakeholders.

Conclusion

Though the difficulty of governing the Seine corridor can be attributed to various factors, the absence of a comprehensive territorial strategy, coupled with the inadequacy of resources granted by the central state, is clearly fundamental. An examination of the achievements made within the corridor over the last few decades reveals that direct involvement of the state is essential when it comes to the mobilization and involvement of local actors. The role of the Seine–Normandy

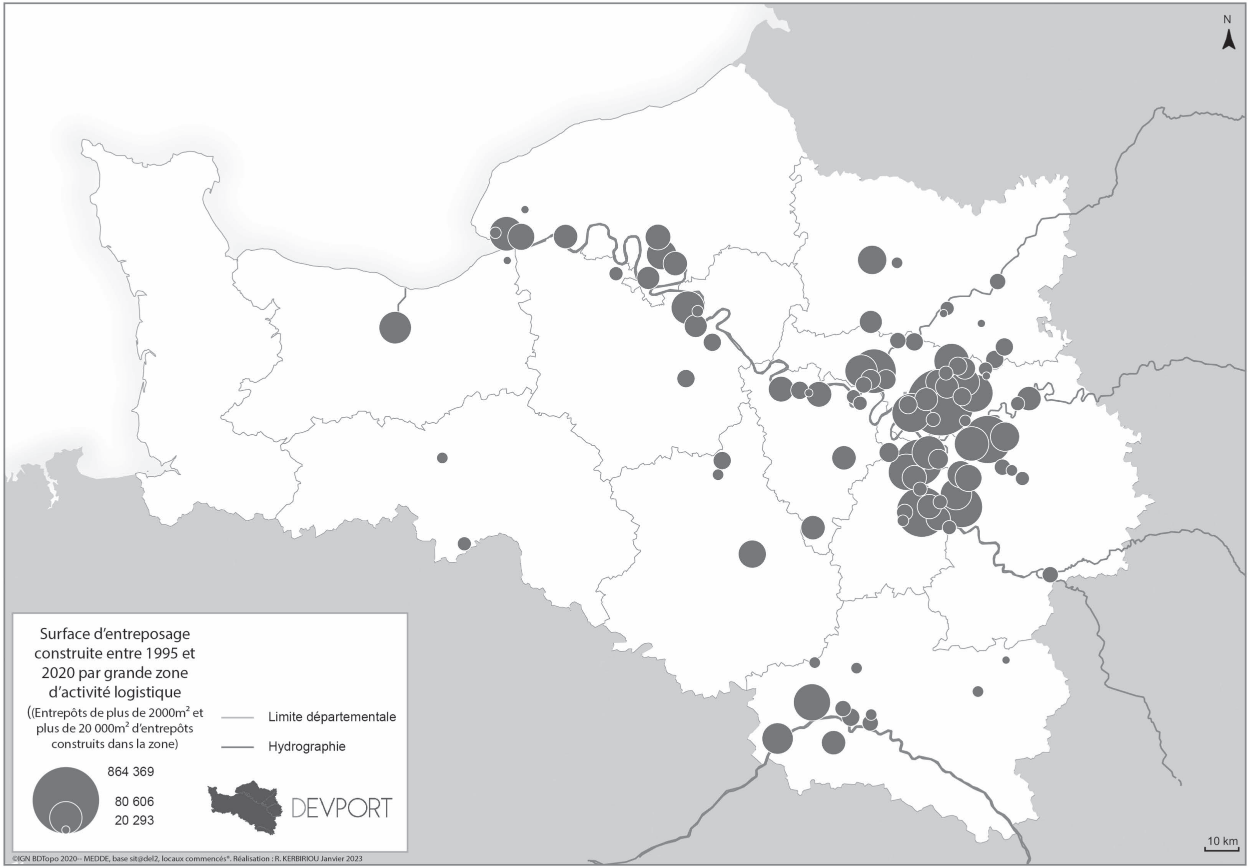

Figure 9.1 The construction of logistics zones exceeding 20,000 m² between 1995 and 2020.

Realization: Ronan Kerbiriou, 2022.

Water Agency created by the state has been crucial in improving river water quality and restoring biodiversity. The completion of the Serqueux–Gisors rail freight line in 2021 is another illustration of the decisive role of the state in the implementation of projects within the Seine corridor (Guihéry, in this book). In addition, the state's decision to merge the three ports in the Seine Valley in 2021 pushed other actors within the corridor to plan and coordinate at this scale to enhance their levels of interaction and visibility. Conversely, when the state adopts a passive approach or delays in taking action, as was the case with the proposed new rail line along the corridor between Paris and Normandy, local actors are often unable to execute collective and coordinated strategies capable of offsetting or compensating for the central government's stance.

The situation in France highlights the challenges of coordinating and implementing development projects in corridors organized as weakly institutionalized soft spaces. The vast geographical scale of these corridors, the number of actors involved, and the significant financing required for their development are not compatible with flexible and poorly centralized cooperation. It remains to be seen whether this constraint is unique to the French political model of territorial governance, characterized by persistent, albeit tempered, centralism, or whether it can be observed in other, more decentralized institutional contexts.

Notes

1 See also Libourel and Schorung for the Mediterranean corridor in Europe and the NAFTA corridor (2016). See Chapman et al. (2003) for the corridor linking the West Midlands to the London corridor in England.

2 The Société nationale des chemins de fer français (SNCF) (National society of French railroads) is a publicly owned company that was nationalized in 1937. It serves as both the manager and operator of the railway network in France. In recent years, there has been a gradual opening up of the network's operation to private companies, allowing for competition.

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10 The corridors of landlocked Ethiopia

François H. Guiziou

Although there are articles that discuss landlocked states in literature, and which refer more or less directly to African states and African regions (including Hoyle & Charlier, 1995; Debrie & Steck, 2001; Debrie, 2010; Oliete Josa & Magrinyà, 2018; Ducruet & Guerrero, 2022; Faye, McArthur, Sachs, & Snow, 2004), none of these works focus specifically on the transportation system in Ethiopia and the Horn of Africa region.[1] With a population of 115 million inhabitants (World Bank, 2021), Ethiopia has featured on the list of landlocked countries since its separation from Eritrea in 1993. The situation worsened in the wake of the conflict between the two countries from 1998 to 2000, resulting in the loss of the two major Eritrean ports of Massawa and Assab (along with the latter's refinery), previously serving as the major port for the corridor leading to Ethiopia's capital region, Addis Ababa. Following the closure of the Assab corridor, traffic was diverted to Djibouti, which seized the opportunity to invest in its harbour facilities and position itself as the principal access point to Ethiopia, particularly the capital area, which is the main urban-industrial zone in demographic terms (four million inhabitants and over 1,000 companies, according to the United Nations Development Program [UNDP], 2018). Since the late 1990s, the Ethiopian authorities have sought to reduce their reliance on Djibouti, while also working to preserve and modernize this critical transportation route. As a result, alternative regional corridor projects have emerged. However, doubts have been raised over the capacity, both financial and political, of Ethiopian authorities to succeed in this diversification strategy.

This case study aims to illustrate the challenges faced by landlocked countries when developing multiple entry routes to avoid territorial isolation, particularly in the face of recurring and major security issues in neighbouring states. Although this study does not provide an exhaustive list of all the corridors and projects involved, it has four main objectives: (1) to provide a characterization of the Ethiopian hinterland served by its principal corridor, the port of Djibouti; (2) to describe the situations in the neighbouring seaports of Berbera and Assab, which are also major parts of Ethiopia's transportation network; (3) to examine alternative projects aimed at opening up the region; and (4) to discuss the sustainability of this strategy, with a particular focus on security concerns.[2]

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Ethiopia's main hinterland: the capital region

The capital region and its neighbouring territories are the lifeblood of present-day Ethiopia. Addis Ababa, a relatively recent city (established in 1886), owes much of its rapid development to its historic connection to the port of Djibouti and the French railway (a service that ran between 1901 and 1917). As a result, three states – Eritrea, Djibouti, and Somaliland (a proto-state born out of the Somali civil war) – share 450 km of coastline. In general, three ports provide effective access to landlocked Ethiopia and its capital: Assab (900 km from Addis Ababa), Djibouti (at an 850-km distance), and Berbera (at a 950-km distance). The location of these ports is highly advantageous from a geomorphological standpoint: (1) because they provide access to the hinterland, which is limited at certain grades because of the natural barriers of the Great Rift and the Awash Valley, as well as to the Ethiopian highlands in general; (2) with regard to the tectonic foreland, because these ports are located in close proximity to the international Bab el-Mandeb Strait, which is an extension of the rift and a site of intense global traffic (in which these ports only participate to a marginal extent) and, at the regional scale, where these ports are very well integrated.

The vast majority of the traffic in this main corridor is by road.[3] The axes of these major ports towards the capital region converge at Awash at the A1 junction, the A10 junction, and the reinforced track passing through Dire Dawa (central–eastern corridor), as shown in Figure 10.1. An alternative route is the B11 road (Mile) and then the A2 road (Kombolcha), which offer lighter traffic volumes at the cost of a steeper road. The Ethio–Djibouti railway takes a more southerly route through Dire Dawa, joining the A10 road coming from the Somali border and the Berbera road (eastern corridor). Finally, an important road connection with the major Djibouti/Assab corridor in the Amhara region is located in the east (via the B21, B31, and B22 roads). These routes combine to form a corridor, with Djibouti serving as the undisputed central hub, Assab taking on a marginalized status, and Berbera positioned as the newcomer. However, they share a comparable hinterland: the capital area (for the three routes); the Afar region and the Amhara region (for Assab and Djibouti); and the northern Somali region (for Djibouti and Berbera). Furthermore, these routes ensure, by means of irrigation systems from the capital region, the supply of a significant part of the country.

The centre–periphery relation is heavily marked by Addis Ababa's political and demographic weight, as well as its attractive power.[4] In addition to the central–eastern corridor (also known as the "Black Ribbon"[5]) and the eastern corridor mentioned earlier, the other road corridors serving the majority of the population from Addis Ababa are distributed as follows: the northern corridor towards Mekele and Zalambessa–Kokobay (Eritrean border); the northwestern corridor by Gondar towards Aksum; the western corridor towards Nekemte, Asosa, and Kurmuk (Sudanese border); finally, an axis extending southward to join the Kenyan border with Moyale, following the Rift Valley (A7–A8 highways). All these roads and railways are subject to both arid and tropical climates. Because of the risks associated with these climatic characteristics, such as floods, landslides, and fires, costly maintenance is required for these corridors to operate at full capacity.

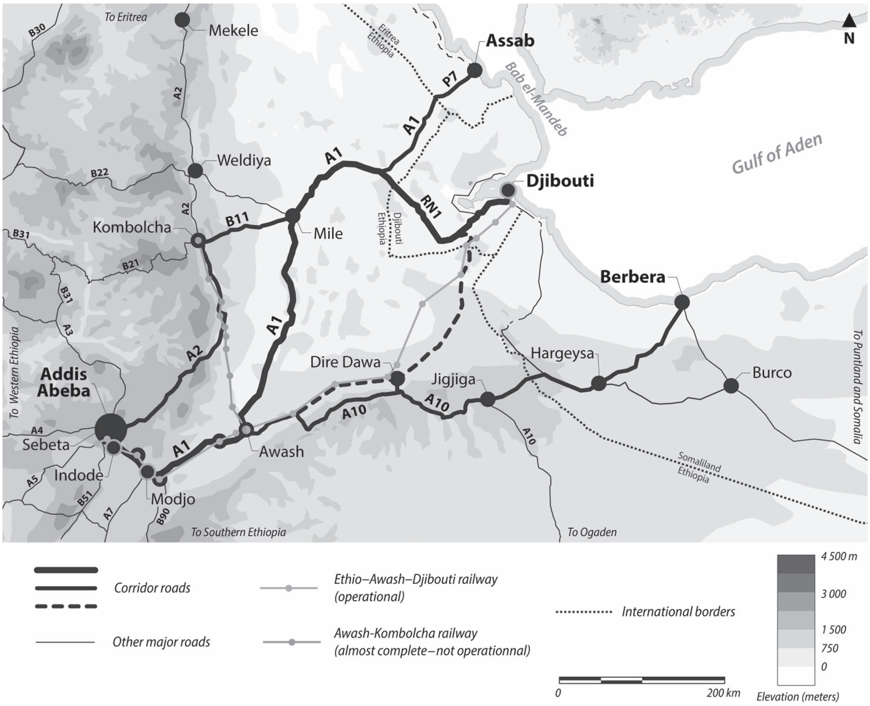

Figure 10.1 The Ethio–Djibouti corridor, Berbera, and Assab.

Source: map created by the author.

The Djibouti corridor

The port city of Djibouti, a product of French colonization established in 1883, is currently the principal port serving Ethiopia. Despite a lack of any statistical backing, it is often claimed that more than 90% of goods officially entering the Ethiopian territory transit through its harbour facilities (United Nations Conference, 2013). The port comprises several installations, including the old port (the Port authority of Djibouti, which is now dedicated to bulk cargo and warships calling); the Doraleh container terminal managed by the Société de gestion du terminal à conteneurs de Doraleh (SGTD) (Doraleh Container Terminal Management Company), established in 2009; eight gantry cranes, initially developed and operated by Dubai Port World (DPW) until their expulsion in 2018, (cf. infra); the oil port of Doraleh (Horizon Terminal Djibouti, established in 2005); and the Doraleh Multipurpose Port (DMP), a general port built by a Chinese company in 2017 comprising four gantry cranes. The current capacity of the port of Djibouti is around 1.2 million TEUs (20-ft equivalent units). Two other, smaller, export-focused facilities, the Tadjourah terminal (dedicated mainly to Ethiopian potash, established in 2017) and the port of Ghoubet (salts, since 2017), complete the port landscape. Since 2003, all these facilities have been under the supervision of the Djibouti Ports and Free Zones Authority (DPFZA), a government agency that manages and coordinates the development of new terminals and infrastructure. The port infrastructure of Djibouti meets international standards, and the Djiboutian authorities are currently discussing new developments such as the ambitious industrial park project of Damerjog, which would include the installation of a refinery (while putting original plans for a livestock terminal, which is currently functioning as a quarantine yard, on hold). The initial works, started in 2020, are still in the early stages and currently limited to the construction of a jetty and a terreplein.

Although a very large part of traffic between Djibouti and its hinterland is by road (the RN-1 National Highway and then the A1 road), it is hoped that the construction of an electric railway will increase the amount of traffic bound for Adama in Addis Ababa, as well as industrial facilities in Dire Dawa and Awash. Just a stone's throw away from the route of the first road laid out by French engineers at the beginning of the twentieth century, this Chinese-built railway is the primary argument put forward by the Djiboutian authorities in demonstrating their competitive edge over rival ports. Container capacity could offer a maximum capacity of 100,000 TEUs[6] per year – assuming that three freight trains were to operate at full capacity every day – which would amount to approximately 10% of SGTD and DMP's transit per year. The route provides several benefits, including shorter distance, enhanced safety, as well as smoother traffic flow, achieved by minimizing load breaks caused by the prevalence of roads and the time-consuming process of emptying and loading containers onto trailers (United Nations Conference, 2013). Among the eight Ethiopian dry ports, those of Modjo and Indode have rail-mounted stacker cranes and so are well-equipped for container management and enable efficient exports to the manufacturing zones around Addis Ababa (Akaki, Kality, Sebeta, Feri-Lebu, etc.). It is worth noting that this dry-port strategy is also utilized for major roads, albeit in a more rudimentary way, that is without dedicated multimodal infrastructure. This illustrates the synergy between the A1 and the railways, which have played a significant role in creating a thriving industrial corridor between Sebeta and Adama, comparable in scale to those found in the Horn of Africa. Furthermore, the importance of Awash, with its gasoline reserves, and Dire Dawa, known for its cement production, both situated along the railway, cannot be overstated.

The frequent meetings held between the Ethiopian and Djiboutian authorities demonstrate their intention to proceed with caution in their fledgling partnership, despite Ethiopia's clear desire to diversify access to the sea. For Djibouti, the stakes are very high, since the state budget is heavily dependent on the port revenue generated by Ethiopian trade (20–25%, World Bank International Finance Corporation, 2014, and the security provided by the foreign detachments stationed on its territory (France, the United States, China, etc.). Despite being a small state, Djibouti's strategic location has attracted the accumulation of forces of allied and competing states in the international arena, making it a curious case. The reasons behind the presence of these foreign actors are manifold: antipiracy, counterterrorism, strategic positioning in the vicinity of the Bab el-Mandeb strait, and so on. Except for China – which is a crucial partner for Ethiopia – and France – which has a long-standing relationship with Djibouti – these foreign actors have no direct and significant interest in the politics of the Horn of Africa.

The emergence of Berbera and the Assab hypothesis

In recent years, Djibouti has seen the emergence of a potential competitor: the port of Berbera (Figure 10.2), Somaliland's unique port. The port of Berbera has a long history, with ships first throwing anchor there back in ancient times. Its first major dock was developed by the Soviets in 1967, to be expanded by the Americans in the late 1980s, to then thrive in the modern commercial landscape thanks to the help of DPW. However, the Emirati company moved its operations to Somaliland in 2016 because of the political and financial difficulties gripping Djibouti in 2014. These difficulties led to the company's expulsion from Djibouti in 2018, despite the commercial success of the Doraleh terminal of which DPW was manager and remains joint owner. In favour of DPW, the London Court of International Arbitration ordered the Djiboutian state to pay US $500 million.[7] The challenges faced in

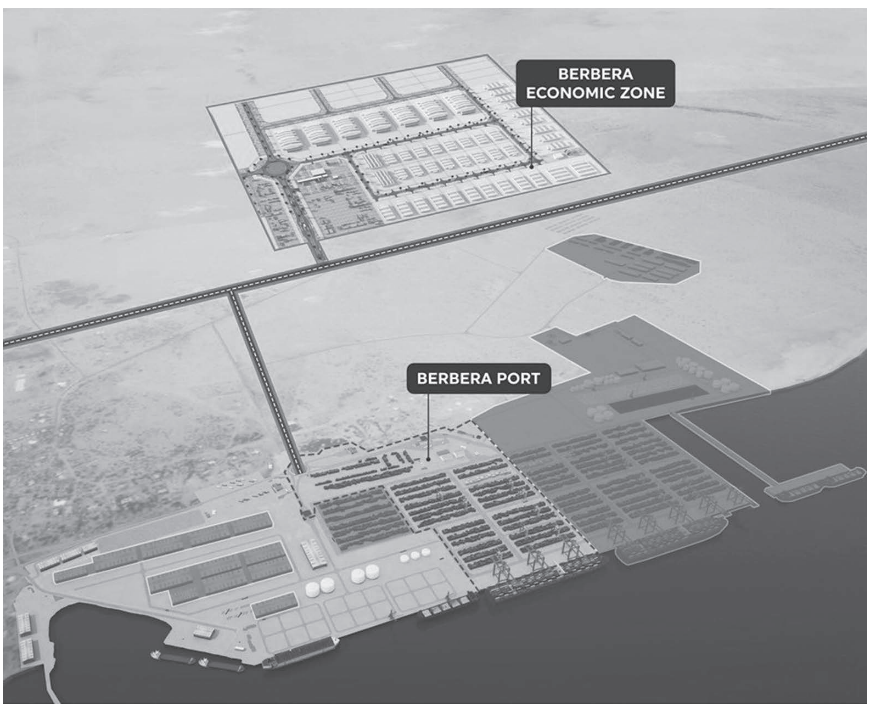

Figure 10.2 Dubai Port World Berbera Masterplan.

Source: image sourced from Wikicommons.

Djibouti prompted DPW to seek solutions elsewhere. Back in 2016, the company obtained a 30-year management contract for the Berbera port facilities from the Somaliland government. DPW then embarked on a $442 million project to modernize the port, significantly improving harbour management and almost doubling the wharf line (1 km in total). DWP also developed a container terminal spanning 33 ha. This terminal is equipped with three gantry cranes, with an estimated capacity of more than 350,000 TEU counters at startup in 2021, up from the previous capacity of 100,000. Long confined to being a bulk and cattle port, Berbera is now the only port in Somalia to have a dedicated container terminal built to international standards.

The Djiboutian conflict offered Berbera the opportunity to welcome one of the major players in international maritime trade. Indeed, DPW is present in 40 countries worldwide and handles around 10% of global container traffic. Prior to this, Berbera was already an important regional port, offering deep-water access, an ISPS certification obtained in 2006 (International Ship and Port Security Code), and facilities for the Global Food Programme, including two silos and a small oil terminal. The addition of a competent container terminal modelled on the Doraleh facility, boasting a free zone and a focus on regional industry development, harks back to the rise of Djibouti. Berbera now stands as a key competitor that could disrupt the Djiboutian hegemony. The recent agreements with Ethiopia in 2000 and 2016, the official docking of the Ethiopian Shipping and Logistics Services Enterprise ships since 2021, the new free zone law enacted in Somaliland in 2021,[8] as well as the DPW's tariff policy (Table 10.1), are all factors contributing to the port's immense success, with support from Ethiopia also playing a crucial role in its rise to prominence. Ethiopia sees Berbera not only as a complementary option to the Djibouti axis but also as a necessary step forward for the industrial development of its eastern regions.

What the Ethiopian government and logistics actors see as complementarity is in fact a power struggle between Djibouti and Berbera to capture the other's market share. While Djibouti is striving to maintain its lead, Berbera has the advantage of opening up a previously neglected hinterland. This hinterland includes Somaliland, with its population of around 5–6 million, and its capital Hargeysa, which has over one million inhabitants. A bypass currently under construction will help to

Table 10.1 Tariffs (one movement) for a normal container (USD) at Djibouti and Berbera container terminals (DPW Berbera Tariff Book, 2021; Société de Gestion du Terminal de Doraleh (SGTD) (Doraleh Container Terminal Management Company) Tariff Book, 2021).

	Djibouti		*Berbera*	
	Up to 1 TEU	*Over 1 TEU*	*Up to 1 TEU*	*Over 1 TEU*
Discharging/charging full	133	166	130	195
Discharging/charging empty	94	121	80	120
Transhipment full	141	201	141	175
Transhipment empty	112	137	124	159

streamline the dense traffic linked to the corridor. The main hinterland of this corridor is the Ethiopian ethno-federal region populated by Somalis (6.4 million inhabitants, Ethiopian Statistics Service, 2022[9]), mainly up to the town of Dire Dawa and encompassing the entire Ogaden. The main choke point of traffic flows is the "border city" of Jigjiga, the capital of the ethno-federal region. This city is a busy transit zone located 70 km from the Tog Wajale border post. This corridor handles the majority of export livestock destined for the countries of the Arabian Peninsula, the majority of food aid destined for Ethiopia (65% according to widely cited figures), as well as an increasing share of bulk and container cargo bound for Dire Dawa and the capital region via the A10. The secondary corridor's road network has been continuously strengthened since the end of the 2000s, which bodes well for its change of status and the possible capture of traffic in the Djibouti area. For Somaliland, there is also a major political question at stake, since asserting itself as a state and partner of Ethiopia allows it to partially guarantee its sovereignty in the face of a still non-functional federal Somalia, as well as to further assert its status on the international scene (Stepputat & Hagmann, 2019; Tahir, 2021).

Finally, the position of the port of Assab remains open to speculation. Boasting high-quality infrastructure developed by the Soviets, and located in the immediate vicinity of the Bab el-Mandeb Strait, the port of Assab was recently used by the United Arab Emirates for military operations in Yemen (2015–2021). This port offered the immense advantage of housing Ethiopia's one and only refinery whose operations were shut down in 1997. Following the re-establishment of relations between Ethiopia and Eritrea in 2018 (Ethiopia and Eritrea, 2018), plans were made for Arab pipeline projects in Assab, but none have seen completion.[10] Though the port remains limited in capacity (seven berths, no gantry cranes), it does offer scope for improvement and a quality anchorage. In the short or medium term, however, it does not seem likely that Assab will reclaim its position as a major port facility.

Other corridors

The opening of corridors to Ethiopia via Port Sudan and Suakin (Sudan), Massawa (Eritrea), and Mombasa and Lamu (Kenya) also opens up other, albeit more marginal, flows (Figure 10.3), which represent alternatives to the eastern axis in terms of serving the peripheral regions of Ethiopia:

- The Sudanese corridor starts from a road that leads to Metemma (the principal border post on the high plateaus); the Amhara area and to the towns of Gondar (400,000 inhabitants); and Bahir Dar (300,000 inhabitants). Despite operations being hindered by Sudanese political difficulties, the ports remain functional. They are however distant from the Ethiopian border (950 km), which significantly limits the volume of flows.
- The Massawa corridor, which primarily serves the Eritrean capital, Asmara, and to a lesser extent, the northern region of Ethiopia via Kokobay the border post (320 km), has the potential to facilitate transport access in Ethiopia. In this vein, the construction of a motorway on the Mekele–Kokobay stretch in Ethiopia has

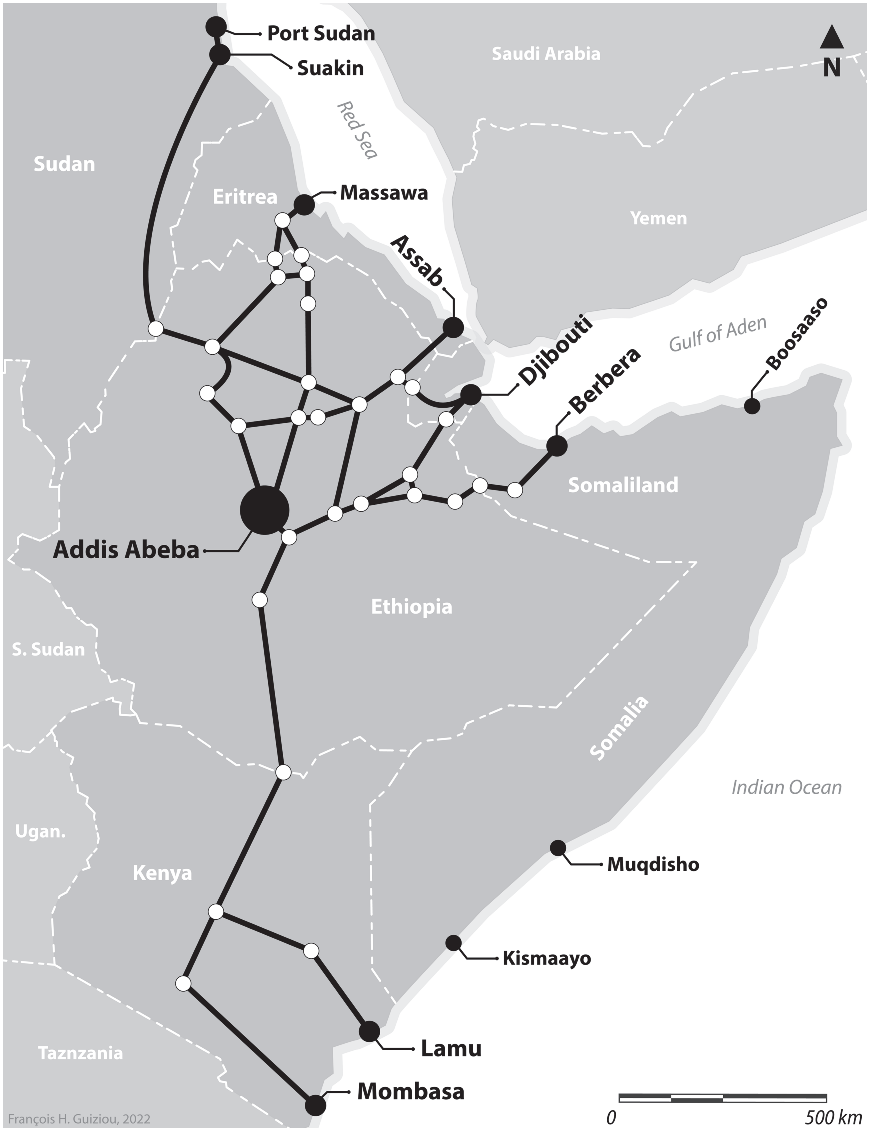

Figure 10.3 Current and potential corridors in the Addis Ababa Region.

Source: map created by the author.

been completed. However, due to the ongoing conflict in the region, this corridor currently offers little value in terms of supporting the Ethiopian national diversification strategy.

- The Kenyan corridors, comprising the Mombasa–Isiolo–Moyale and Lamu–Isiolo–Moyale axes (spanning 1,260 km and 1,200 km respectively), serve as gateways towards the south. Though the former offers limited flow, the latter (currently still under construction) is a large-scale Chinese project: the Lamu Port and Lamu–Southern Sudan–Ethiopia Transport (LAPSSET) Corridor. Its first quays became operational, after a decade-long delay, at the beginning of 2022. The purpose of these quays is to facilitate the movement of materials needed to complete the corridor, including roads, railways, and power grids that will connect the southern part of Ethiopia. The first phase of the project, which has already been completed, had a preliminary budget of US $400 million dollars and will pave the way for subsequent new phases, culminating in a total cost of US $25 billion dollars upon completion. By 2065, the colossal project is expected to interconnect on a regional and continental scale, extending all the way to the north-eastern region of Kenya, which has a low population density of Somali Kenyans. This project will therefore serve as a crucial international corridor bound for the South of Ethiopia and South Sudan, which represents the most significant market in the region.[11]

In summary, the ports of Somalia – excluding Berbera – such as the ports of Bosaso, Muqdisho, and Kismayo, cannot claim to be anything more than weak supply lines for the Somali territory. This applies to the informally organized Somali areas that extend from Djibouti to Kenya via Ethiopia. Despite the diverse nature and spatial organization of these flows, they are all limited in terms of tonnage and financial volumes.

Conclusion

Industry development in Ethiopia, whose added value exceeded US $21 billion in 2020 – a five-fold increase from a decade ago (World Bank, 2021) – has resulted in a considerable reduction in the cost of importing and exporting containers. The corridors in Ethiopia could therefore potentially provide a leverage effect. However, two key issues remain:

- First, there is the heavy dependence on external funding and construction and regional-level competition to attract traffic, as illustrated by the ongoing rivalry with Berbera Port in Djibouti. The corridors clearly operate within a strained diplomatic environment, marked by a complex interplay of economic and diplomatic factors, which often extends beyond the borders of Ethiopia. It should be remembered that Djibouti and Berbera enjoy the advantage of guaranteed security by international external actors: China, the United States, and France for Djibouti and the UAE for the Berbera region (Larsen & Stepputat, 2019). Though successful, this added layer of maritime security may come at a cost, as it entails a strong reliance on local political actors. In the event of changes to international or regional strategic (and economic) objectives involved on a local level – such as the intervention of UAE in Yemen; Eritrea's involvement in the Ethiopian civil conflict; or fierce competition between the United States and

China in the Indo-Pacific sphere – there is every chance that existing strategies will change rapidly.

- Second, there is the issue of regional security. Excluding Ethio-Eritrean relations, which shook the transport landscape at the turn of the century, the Tigray rebellion placed enormous pressure on the Djibouti corridor when the front line came near Mile on the RN1-A1. The capture of this city would have resulted in the disruption of the supply to the capital region and its probable collapse. Furthermore, the Somali and the Oromo regions are still plagued by conflictual trends that lead to a considerable slowdown in transportation and project development. Similarly, the buffer zone established by Kenyan forces during Operation Linda Nchi (2011–2012) and its subsequent developments, particularly in support of the frontier Somali area of Jubaland, aimed to prevent the spread of Somali Islamist insurrection promoted by the militant organization Al-Shabaab in the area where the Lamu–Moyale corridor will be constructed.

Thus, in order to bridge the gap between marginal and central regions and mitigate Ethiopia's extreme centre–periphery divide, significant public investment is required, and, even then, at least a minimal level of security must be in place for ventures to prove profitable. However, it is difficult to envision the feasibility of this strategy for the heavily indebted Ethiopian state, which lacks the resources to simultaneously handle internal, high-intensity armed conflicts and pursue major infrastructure plans. This represents a major obstacle to Ethiopia's development. All things considered, the case study of Ethiopia presented in this chapter could provide an excellent illustration of the concept of "inversion territoriale" ("territorial inversion"), a term coined by Debrie and Steck in 2001. The authors used this term in the context of West Africa to describe the development of transport routes by inland countries as a means of reversing their landlocked status. As with their description, we can see that strong inter-port competition is driven by the desire of the Ethiopian giant, with its huge population and economic potential, to expand its market reach and free itself from its dependence on the port of Djibouti by diversifying its access routes. Though this shift is still in its early stages because of the limits mentioned earlier, it underscores the need to re-evaluate Ethiopia's current status as a landlocked country.

Notes

1 Only Hoyle and Charlier's article (1995) deals specifically with East Africa (Kenya and Tanzania), and it only makes passing references to Ethiopia.

2 The research method was based on: (1) the study of satellite imagery, (2) internet sources related to the topic (mainly official reports and specialized websites), (3) a network of local informants, and (4) two interviews with academics from the region (non-specialists in the field of transportation). A literature review on corridors was conducted prior to the study. Due to the security situation in Ethiopia, it was not possible to conduct fieldwork.

3 Ethiopia's Climate Resilient Transport Sector Strategy (2020). www.mofed.gov.et/media/filer_public/15/31/153174c3-b472-4339-b3bb-fb2c48cad629/transport_cr.pdf

4 It should be noted that, in addition to Ethiopia's current landlocked status, there are two other landlocked situations at the infra-national level: one from the highlands to the

lowlands encompassing the Afar, Somali, and Oromo regions, and the other from the northern highlands (Tigray region) to the southern highlands (Amhara region). These complexities create significant challenges for Ethiopian policy makers in terms of establishing an ethno-regional balance and addressing tensions related to development and infrastructure choices.

5 Interview with an Ethiopian expert, 1 July 2022.

6 Ethiopian Railway Corporation (2021); personal findings.

7 www.reuters.com/world/middle-east/dp-world-says-wins-ruling-against-djiboutis-port-company-2021–07–12/

8 www.somtribune.com/2021/01/08/somaliland-passes-free-trade-zone-law/

9 *Population Projection Wereda as of July 2021*, Ethiopian Statistics Service (2021).

10 www.thecaireview.com/tahrir-forum/saudi-arabia-and-the-uae-look-to-africa/; www.bloomberg.com/news/articles/2018-10-21/dp-world-sees-key-role-for-once-isolated-state-in-port-strategy

11 Some analysts have dubbed this project a "white elephant" due to its slow development and security issues (interview with a researcher, 8 September 2022).

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Third section

Towards digital transition to optimize logistics corridors

11 Enhancing global supply chain performance by optimizing port resources

Gülgün Alpan, Hamza Bouzekri and Éric Sanlaville

Introduction

Operations research (OR) can be defined as a set of analytical methods and techniques oriented towards the search for the best possible choice or decision (e.g. order of vessels to be loaded) to reach a desired goal (e.g. minimize vessels' total port call duration). OR methods make extensive use of mathematical and process modelling, are powerful for analysing complex situations, and are effective in decision-making. The application areas are numerous, ranging from logistics to financial assets optimization, at all decision levels, from strategic to operational. In this chapter, our focus is on decision problems in logistic corridors involving ports.

Numerous decision problems arise in ports. We present the major operational problems in this chapter and give an overview of how OR tackles such problems. While ports are crucial in a global supply chain, they cannot be considered as "stand-alone" units. Indeed, the decision problems related to ports are highly interlinked with any decisions taken along the logistic corridors leading to ports, as well as along maritime routes exiting ports. This high level of interconnectivity creates both challenges and opportunities for the OR community. Here, we will focus on some recent advances in integrated approaches in OR, where one or more decision problems are tackled at the same time. We present some classical integration approaches and provide a case study from the phosphate supply chain.

Port management and beyond

In this section, we will present major decision problems in managing port operations, without attempting to be exhaustive. The focus will be on operational issues. The decision problems at the operational level mainly concern the planning and scheduling of scarce resources or bottleneck spaces in the ports.

Seaside decision problems

The most significant seaside problem in port operations is the berth allocation problem (BAP). It refers to the operational problem of assigning berthing positions and times to every vessel to be served within a short-term planning horizon (one

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to two weeks), such that certain performance objectives are attained (Bierwirth & Meisel, 2010, 2015). The objective could be, for example, to optimize berth utilization, berthing time, or certain cost metrics binding port operators to shipowners through contract clauses. The assignment must respect the constraints of the problem, such as vessel lengths and draughts, expected arrival times, and predicted handling times. A related problem is the laycan allocation problem (LAP), which refers to the tactical problem of assigning berthing time windows (laycans) to new vessels within a medium-term planning horizon (three to four weeks), by taking into consideration constraints such as the availability of cargo and port resources (Bouzekri et al., 2021). Hence, the LAP provides a preliminary berthing plan prior to the BAP, with the aim of ensuring that the required resources are aligned to provide the service clauses agreed in a contract between the port management and the vessel operators. A laycan ensures the feasibility of port operations, but the effective use of resources can only be achieved through solving the BAP.

Besides berths, quay cranes are also a scarce resource in container terminals. The number and the productivity of quay cranes assigned to each vessel heavily impact vessel-handling times. As berths remain occupied during this period, scheduling quay cranes is possibly the second most important and intricate element of container terminal seaside operations. As a result, the quay crane allocation problem (QCAP) is studied widely (Bierwirth & Meisel, 2010, 2015). QCAP involves the assignment of a number of quay cranes to each vessel for loading and/or unloading operations. The assignment must respect the constraints of the problem, such as the number of cranes available at the quay and the non-crossing constraints of quay cranes if they are mounted on rails. In the QCAP, all quay cranes are assumed to be homogenous and interchangeable. This assumption is relaxed in an extension of the problem known as the specific quay crane assignment problem. In this version, each crane has specific characteristics and is individually assigned to vessels.

Two versions of both quay crane assignment problems have been tackled in the literature: time-invariant and time-variant (variable-in-time). In the time-invariant version, the crane assignment to each vessel is fixed throughout its handling time, while in the time-variant version, the crane assignment can vary throughout the loading/unloading operation. The latter version facilitates a more efficient use of cranes since it allows them to be reassigned. However, this can result in a greater number of crane movements, which is complicated to manage both on the field and as a decision problem. Indeed, the number of decision variables in the time-variant version is greater than that in the time-invariant version, which makes the problem more difficult to solve. Both versions are interesting in practice and for the OR literature.

Many other planning problems are relevant, such as the container stowage problem (Ambrosino et al., 2004) which deals with the positioning of containers in vessels, but these problems will not be discussed in this chapter.

Yard-side decision problems

Yard planning is essential for efficient operations in container terminals, especially since ports have limited storage space. Flexible management of storage space planning strategies is necessary to improve the utilization of port space and the efficiency of handling equipment.

Regarding yard planning decisions in the context of container terminals, the yard assignment problem (YAP) aims to assign yard storage locations to each vessel to minimize the transport distances of moving containers between berths and yard storage locations (Zhen et al., 2013). A similar problem in the context of bulk ports is the storage space allocation problem (SSAP). Even though the objective of the SSAP and the YAP is assigning storage locations, these problems have major differences due to the constraints inherent to the port context. In the case of bulk products, the storage space utilization might have restrictive constraints which do not exist in the case of container terminals, and vice-versa. For instance dry bulk products cannot be mixed in a storage space to avoid the cross-contamination of products, and cleaning might be necessary between two storage periods, and so on. These specific constraints must be taken into consideration when making decisions on storage space assignment.

The handling equipment and transportation system is also quite different for container terminals and bulk port yards. In the former case, trucks and cranes are used, while in the latter, bulk products are transferred from storage areas to berths through pipelines or conveyors. In both cases, however, routing of cargoes and transportation planning from the yard-side to the seaside must be organized. Due to the differences between the transportation and handling equipment used in bulk ports and container ports, the decision problem to be solved is also different. While for the container terminals, truck scheduling and dispatching between yards and berths are an issue, for the bulk ports, the concern will be routing decisions in conveyors and pipelines. Other related problems include the container relocation problem, which attempts to minimize the number of relocations when retrieving containers in a simpler setting, and the vehicle dispatching problem, which assigns vehicles to containers in order to transport them between the seaside and yard-side.

Other related decision problems and connectivity to supply chains

From a supply chain point of view, operational decision problems can extend further towards the sea (maritime logistics) on one end or the hinterland (terrestrial logistics) on the other end. Ports are the strategic link between the two. Operational problems are numerous on both ends of supply chains. As an example, we can cite the ship routing problem, which concerns maritime logistics and last-mile logistics regarding the hinterland (Li & Pang, 2011).

Decisions related to the problems outlined earlier can be made sequentially. However, this could result in suboptimal performance in port operations since the decisions are strongly linked to one another. Figure 11.1 illustrates the hierarchy of some of the decision problems described earlier in a downward direction, and the feedback between them in an upward direction (slanted arrows).

Indeed, the allocation of laycans to new vessels depends on the availability of port resources, mainly quays, and the expected cargo availability dates. If laycans are fixed independently, this can cause excessive overloading in

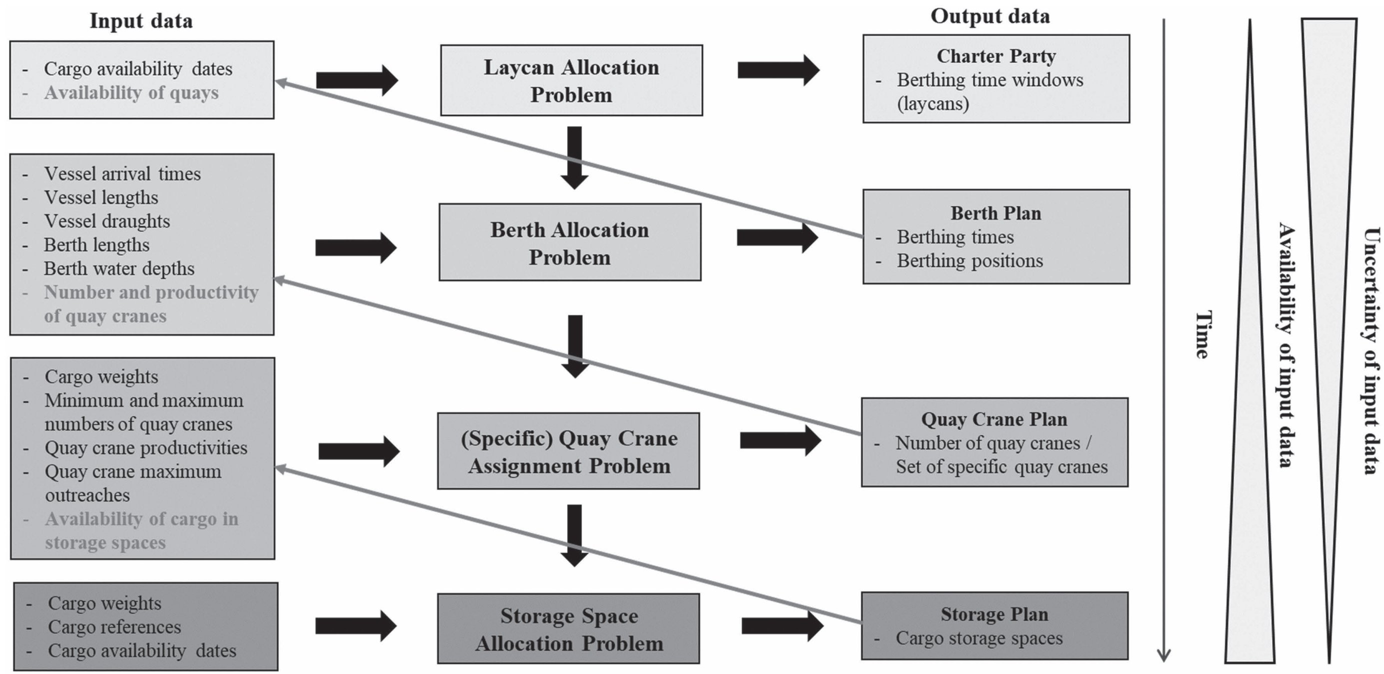

Figure 11.1 Interrelations between port planning problems (Bouzekri, 2022).

the execution of port operations and high waiting times for vessels. In addition, the number and the productivity of quay cranes and routing constraints between storage spaces and berthing positions affect vessel stay times in the quays. Failure to account for all of these existing interrelations will lead to poor-quality decisions. This is why there is a growing interest in adopting integrated approaches to guarantee supply chain alignment, which is considered one of the major factors for improving overall performance. The difficulty does lie not only in optimizing the decisions at each individual echelon of the supply chain, but also in optimizing the decisions across every echelon, from the production of goods to their expedition. This all makes supply chain alignment inherently challenging.

In the next section, we will first give an overview of how to model port operations' decision problems using OR techniques, then we will present two approaches to integrating problems for end-to-end supply chain management.

Modelling and optimization tools

OR emerged during the Second World War to give scientific answers to operational problems and has developed considerably since its emergence, mainly in large companies and public services. It is particularly useful for offering insight and solutions for problems that involve large amounts of data and is characterized by the search for a solution that optimizes a given quantitative criterion. Such problems are called optimization problems. OR is successful because it proposes general optimization tools linking modelling and solutions through smartly designed algorithms, starting from the linear programming model and the simplex algorithm developed during the 1940s. A huge effort has since been made, and continues to be made, to propose efficient tools to solve more general decision models, involving binary variables, more complex criteria, several criteria simultaneously, or uncertainties.

From the beginning, OR was used to address logistics problems, as these issues have a significant impact and can be modelled quite well. Port optimization has received a large amount of attention in the OR community, particularly during the last 20 years (see for instance Bierwirth & Meisel, 2010; Schepler et al., 2017). This attention has stemmed from the automation of terminals, the growing amount of data available, and more generally the accelerated evolution of ports and the fact that they are increasingly intertwined with logistics chains.

This section first explains what an OR model is and then considers the difficulty of integrating different decision levels. To help the reader to understand the main issues, we will draw on some characteristics of the case study that is explained in more detail in the last section.

How to model port decision problems

An OR model consists of three parts: the variables, the constraints, and the objective.

Model variables

Usually, one starts with the variables. An optimization problem involves making several kinds of decisions. A given variable might be considered as the translation of one decision to be made. Port optimization problems can be viewed as planning problems. Thus, decisions must be made regarding the use of resources, such as how resources and time (beginning time, duration) are assigned to these tasks. Hence, a variable may be a Boolean variable (a yes/no decision), an integer variable (a choice between several alternatives), or a continuous variable (a fixed time or amount). However, modelling is more than directly translating an operation problem into a modelling language. Indeed, there are modelling choices to be made, and it is crucial to draw from experience at this stage.

For instance let us consider a vessel calling at a terminal to load some bulk (like fertilizer). The terminal manager must first decide to which berth to assign the vessel. Often in the model, a variable indexed by the vessel and the berth is used. It can be noted as x_{ij} where i is the vessel number and j is the berth number. The variable takes value 1 if the vessel stops at this berth and 0 if it does not. Then there are the resources to bring the load to the vessel, such as which storage area(s) contain(s) the load (there may be several), which conveyors will be used to bring it to the quay, and potentially which quay cranes should be used – namely, more Boolean or integer variables. And finally, deciding on the time at which the vessel should call at the quay will involve some continuous variables. Note that if all the associated variables are fixed, the time of the vessel departure can be obtained, and so this time is not a model variable. This is true if the model discards uncertainties. Note also that the performance of the operation will depend on the location(s) of the storage area(s) for the load considered with regard to the chosen berth. But usually, these locations are decided by another stakeholder. We will address these questions of integration later.

Model constraints

Suppose the variables have been fixed. We are far from the end of the modelling process. Indeed, the values of variables are subject to constraints, and some of them are not independent. Obviously, two vessels numbered i and i' can be assigned to the same berth j, hence $X_{ij} = X_{i,j} = 1$, but then the starting times of both operations must differ by, at most, the time it takes for the one scheduled first to finish. Moreover, this time depends on other variables, like the quay cranes assigned to the first operation.

Symmetrically, suppose two vessels call at the same time and request the same kind of fertilizer. Then either they must use two different storage areas containing the same fertilizer or use the same area, but this adds the element of precedence between the two loadings. Some auxiliary variables may be needed to fix this order of precedence. Hence, we see that the variable set may be increased as the constraint list is established.

And of course, even for the simple problem of berth assignment, many other constraints may be added, such as those regarding tides and drafts and crane/vessel compatibility.

Objective

In the classical models of OR, the objective is unique. It is a function *f* of the variables. The solution that is the result of an optimization problem consists in fixing all variables so as to maximize *f* (if *f* is a profit) or to minimize *f* (if *f* is a cost or a project duration). For instance in the classical BAP problem, *f* can represent the maximum lateness of the set of vessels considered with respect to individual deadlines. As mentioned earlier, *f* can be computed when each vessel's arrival time, and each vessel's service time, is known. In that case, *f* is minimized.

However, when it comes to real-world problems, things are generally not that simple. Sometimes, computing the value of *f* is difficult or even impossible. In that case, approximations are used, or probabilistic tools, and the model's limitations must be taken into account when considering the obtained solution. It is perhaps even more challenging when there are several stakeholders with different interests involved for a given problem. For instance when considering the BAP or the LAP, the interests of the terminal manager and of the shipping line are different. Furthermore, as mentioned earlier, seaside and yard-side problems are not independent. However, this implies also considering the interests of the storage manager. In the fertilizer exportation case study, the final product is manufactured near the maritime terminal, and storage questions are answered by the manufacturer. There are several possible approaches to tackling the question of antagonistic criteria, and this chapter will discuss three of them. In the first approach, the different criteria are aggregated into a single function. The solution, obtained by classical solving methods, should be a compromise but may satisfy no one. The second approach is the so-called multi-objective model. Instead of building one solution, several dominant solutions are proposed. Here, a solution is dominant, or *Pareto optimal*, if no other solution is better for all criteria. The decision-makers are offered a set of solutions from which to choose one compromise solution. There are two drawbacks to this approach. First, there may be a high number of *Pareto optimal* solutions. Second, the methods to find them may be very time-consuming. An alternative is to decompose the problem into several smaller ones, with the results of one sub-problem being part of the data for another.

Solving

This chapter does not have the scope to explain the solving methods used in OR. Readers who wish to learn more about this subject may refer to the many books that offer an introduction to OR (see for instance Hillier & Lieberman, 2021).

What is important to know is that a significant number of off-the-shelf solvers exist which are fast and versatile (e.g. CPLEX, Xpress, Gurobi). However, when the problem is really big or has special characteristics, ad hoc tools may still be useful. In both cases, finding the best model is often a major issue. A way to increase the performance of a solver is to take advantage of some of the problem's strong constraints to limit the number, or the possible values, of the model variables. This technique is called pre-processing, and it is particularly effective in port optimization where some constraints, like the tidal timetable, may significantly reduce the model size and consequently the solving time.

Integrating port decision problems

As mentioned previously, port operations are highly interrelated and also linked to sea and hinterland operations as all belong to long supply chains. Consequently, recent works seek to propose integrated solutions in which several decision problems are considered together. According to Geoffrion (1999), model integration can be done either by deep integration or by functional integration.

- Deep integration merges two or more optimization problems into one monolithic problem. Consequently, there is no longer a need to make the relations between the sub-problems explicit (these relations are present in the model as coupling constraints between variables associated to the sub-problems). However, it also makes the problem to be solved more complex. As mentioned earlier, a complicated issue is the choice of objective function, as the resulting model contains an aggregated or multi-objective function.
- Functional integration refers to a sequence for solving sub-problems and data exchange mechanisms between the base-level and top-level problems. This integration is the exact reverse of decomposition, but the resulting models are similar. It can be solved either by a feedback loop or by pre-processing.
    - In a feedback loop, the top-level problem instructs the base-level problem, and then the reaction of the latter is used in the top-level to revise instructions (updating variables and sometimes constraints). Once a steady state is reached, the loop terminates.
    - In pre-processing, the base-level problem is solved first to generate more detailed input data for the top-level problem, then both problems are solved sequentially.

Different designs for integrated port operations planning are possible using the integration mechanisms described earlier. In Table 11.1, we provide a non-exhaustive list of examples of integrated approaches reported in the literature. An extensive literature review is provided by Bierwirth and Meisel (2010, 2015) on the papers that solve the BAP and the QCAP (for both homogeneous and specific cranes). In the next section, a case study is presented as an example of functional integration with a feedback loop.

Table 11.1 Examples of integrated port decision papers.

Reference	*Integrated problems*	*Integration type*
Meisel & Bierwirth (2013)	BAP + (QCAP and specific QCAP)	Deep and functional
Schepler et al. (2017)	BAP + QCAP + YAP + inner port transportation	Deep
Fatemi-Anaraki et al. (2020)	BAP + QCAP + waterway scheduling	Deep
Bouzekri et al. (2021)	(BAP + LAP) + (QCAP and specific QCAP)	Deep
Skaf et al. (2021)	Quay crane + yard truck scheduling	Deep
Chargui et al. (2021)	BAP + QCAP + quay crane scheduling + yard truck deployment	Deep
Guo et al. (2021)	BAP + SSAP	Deep
Bouzekri et al. (2022)	(BAP + LAP) + SSAP + production scheduling	Deep and functional

Case study of integrated modelling: from phosphate mining to fertilizer exportation in Morocco

In this section, we present a decision support system (DSS) proposed in Bouzekri et al. (2022) to illustrate integrated planning for end-to-end supply chain management. We will show how interrelations among the studied decision problems are well captured when an integrated problem-solving approach is used.

Context of the study

The DSS has been developed for the OCP Group, a global leader in the phosphate market and its derivatives. The supply chain of the group extends from the mining sites in Morocco, where phosphate rocks are extracted, to the end customers. In Figure 11.2, a section of the supply chain (from Khouribga mining sites to the Jorf Lasfar bulk port) is illustrated. The extracted rocks are first washed in washing plants and then transported by slurry pipeline to the Jorf Lasfar chemical platform. Upon arrival at the chemical platform, phosphate is transformed into phosphoric acid and then into phosphate fertilizers using imported raw materials (sulphur and ammonia). Finally, the finished goods are shipped by vessels to the end customers through the Jorf Lasfar bulk port. Between each one of the supply chain nodes illustrated in Figure 11.2, there are buffer areas where semi-finished and finished goods are stored. At the port yard, there are several hangars, divided into smaller stock units where the fertilizers are stacked before being transferred to berthing positions to be loaded onto vessels. The hangars are linked to the production lines on one end and to the berthing positions on the other end through a complex network of conveyors.

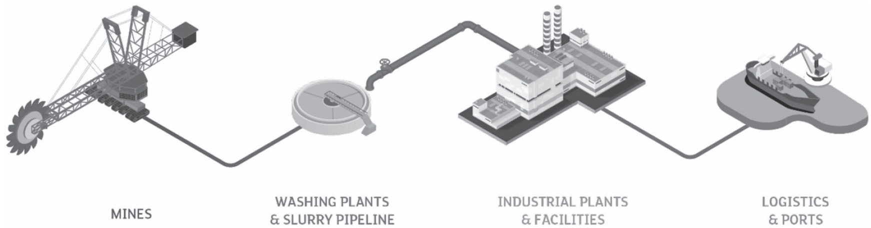

Figure 11.2 Northern Axis of OCP Group (*www.ocpgroup.ma*).

When analysing supply chains, utilizing buffers and stocks can help to break down the supply chain into sections that can be studied separately. To do this, we identify a decoupling point – namely, a strategically placed inventory point in the supply chain. Up to this point, the supply chain can operate using a make-to-stock (MTS) strategy, and then downstream of this point, it can switch to a make-to-order (MTO) strategy, which enables agile management for a swift response to customer demand. It is essential to overcome the variations in customer demand and forecasting errors, while maintaining control over customer lead times. A decoupling point is always an inventory buffer, while the inverse is not true. In the studied configuration, the buffer between the washing plants and the Jorf Lasfar chemical plant is a decoupling point. These inventory buffers clearly form a boundary between an MTS and MTO approach. However, the fertilizer hangars cannot serve as a decoupling point for MTS production. Indeed, the final product varies considerably, preventing the use of hangars as decoupling points. Positioning a decoupling point at the bulk port yard-side would be too costly to implement and inefficient with regard to product diversity. As a result, the fertilizer supply chain can be divided into two parts, before and after the decoupling point, and studied separately. In the following section, we only consider what happens after the decoupling point.

The DSS covers three successive echelons of the downstream fertilizer supply chain, namely the production of fertilizers, their storage, and their removal for shipment by vessels at the Jorf Lasfar bulk port. The decisions that need to be made concern the scheduling of production orders and vessel berthing and the allocation of storage spaces at the hangars. Hence, the objective of the DSS is to align production and storage decisions with vessel demands, ensuring consistency in decision-making and improving supply chain performance.

Decision support system

This planning tool encapsulates a production scheduling model (“production model”), as presented in Azzamouri et al. (2020), as well as a berth scheduling model for bulk ports (“port model”) and a storage space allocation model (“hangar model”), both presented in Bouzekri et al. (2022). The latter model determines where produced fertilizers are stored and where the stored fertilizers are removed from in order to be loaded onto vessels, all while taking into account the constraints

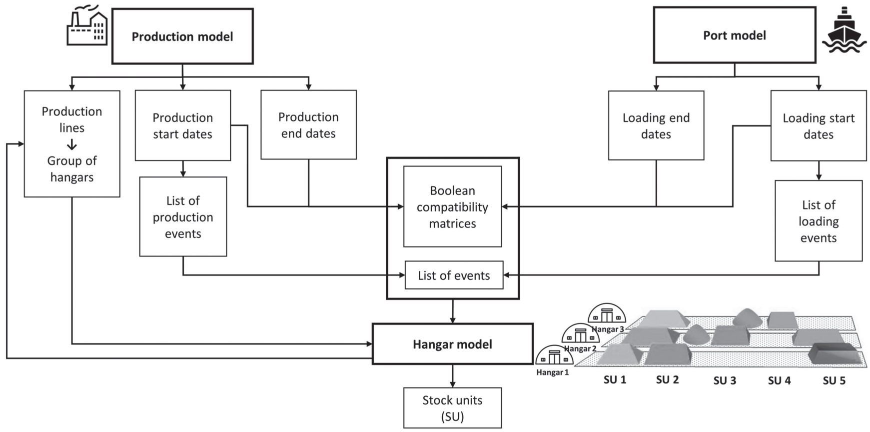

Figure 11.3 How models are interlinked in the proposed DSS.

of the optimal solutions of the production and berth scheduling models, in addition to conveyor routing constraints between production lines, hangars, and berthing positions. Figure 11.3 gives an overview of the functioning of the DSS.

Both deep and functional integration techniques are used. The port model integrates BAP with LAP through a monolithic optimization model (deep integration). The links between the production, port, and hangar models, however, are managed through a functional integration process.

The DSS functions as follows:

- First, the production model generates the optimal production plan that gives each production order its assigned production line and its production start and end dates (production start dates constitute the list of production events); it also yields a Boolean square matrix crossing all production orders where 1 indicates an overlap in their production time. Since each group of hangars is linked to a unique group of production lines, the group of hangars of each production order is also determined.
- Second, the port model generates the optimal berthing plan that gives each vessel its berthing date and position and gives each expedition order its loading start and end dates (loading start dates constitute the list of loading events). The port model also yields a Boolean square matrix crossing all expedition orders where 1 indicates an overlap in their loading time. Then both the production and port models yield a Boolean matrix crossing all production and expedition orders where 1 indicates an overlap in their production and loading times.
- Third, the list of production events is merged with the list of loading events in one list of events ranked in ascending order. Then, the hangar model is launched considering as inputs the resulting outputs of both the production model and the port model to generate a feasible storage plan aligned with optimal production and vessel loading programmes. The storage plan defines the stock unit where

each production order will be stored and the stock unit from where each expedition order will be removed. When the hangar model does not find a feasible solution, it will be relaxed by removing conveyor routing constraints to detect production orders leading up to the conflict. These conflicting production orders are then relocated to another group of production lines. Once completed, the DSS is run again, starting from the port model.

The advantage of the integrated approach is essentially that it aligns decisions at the three stages of the supply chain under study – production, storage, and port – thereby increasing the supply chain's overall performance.

Conclusion

Port performance management has been a focal point both in the industry and in academia for the last two decades. OR provides efficient models and tools that can be used for port management. In particular, several models have been developed to improve the efficiency of seaside and yard-side operational planning for decision-makers in ports. More recently, different integrated approaches have also been proposed to help with the alignment of decisions, guaranteeing effective and efficient solutions that respect all constraints, and to ensure a better propagation of the adopted decisions both upstream and downstream. OR also makes it possible to give more careful consideration to the differing interests of stakeholders. This chapter provides an illustration of these approaches and their usefulness through the case study of the phosphate supply chain in Morocco.

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12 Blockchains for smart ports

Claude Duvallet, Cyrille Bertelle and Mongetro Goint

Introduction

The growth of massified international trade via containerized maritime transport is driving the evolution of ports (Frémont & Parola, 2009). In order to manage the growth of these flows in a context of constrained territorial infrastructure development, it is necessary to optimize services and to make operations as fluid as possible. The digitization of transport documentation and the securing of associated intangible transactions are therefore essential to promoting the fluidity of port passage and the entire transport chain along the logistics corridors. Blockchain is a technology designed to secure transactions, and we will explain how it is intended to accompany the massification of information flows associated with the massification of goods.

Efforts to improve the fluidity of goods and associated transaction flows secured by blockchain primarily target port passage processes, but they cannot succeed if they do not also address the outgoing flow of port infrastructures and therefore the service to the hinterlands and corridors. It is therefore important to cultivate a systematic understanding of this fluidity on the scale of logistics corridors. Furthermore, it is necessary to adopt end-to-end integrative approaches to the port logistics chain, which attempt to coordinate the multiple players under the responsibility of port authorities in their governing activities.

To support this fluidity in an integrative manner, it is important to mobilize fairly specialized skills in terms of innovation and optimization to manage the complexity of logistics, material, economic, and information flows. In particular, it is essential to set up coordinated information systems between players, often called Port Community Systems or Single Windows, as the companies in charge of the development of port information systems, SOGET and MGI, have done for the ports of Le Havre and Marseille, respectively.

Securing the digital transition

Since the beginning of the twenty-first century, the fluidity of port passages and logistics corridors has been based on the deployment of new technologies and their ability to communicate via computer networks. The rapid increase in these networks'

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transmission speeds has opened up possibilities that were difficult to imagine even a few years ago. The widespread use of wireless sensors, RFID (Radio Frequency Identification), and mobile telephony to clearly identify participants is contributing to the development of pervasive environments where digital communication over wireless networks has become the key to innovative services (Watanabe et al., 2021).

The dematerialization of processes is thus made possible with a drastic reduction in human intervention, which is replaced by digital identifiers. But this digital transition poses real challenges in terms of actors' acceptance of and confidence in digital processes that they feel they no longer control. How should legal liability evolve under these conditions should any malfunctions occur? It is now essential to move towards legally recognized or approved digital devices in the event of a dispute. Digital trust is thus the real key to an efficient and productive digital transition. Blockchain technologies claim to be able to provide such devices, and many lawyers are very active in advancing distributed ledger technology law capable of providing legal evidence to blockchain anchors (Barban & Magnier, 2019; Bouchard, 2020).

In addition, a new challenge has become essential in the management of port and corridor logistics. This is environmental preservation, which is vital for the development of truly sustainable solutions. The cost of deploying new technologies and digital technology inevitably raises the question of the sustainability of envisaged solutions. The rise in computing power at the end of the twentieth century led to a maturation towards this digital transition which may have appeared chaotic as both hardware and software evolved at a speed that undermined the stability of the necessary management systems. The completion of the design of modular information systems, concern for interoperability, and communication standards are becoming essential issues around which stakeholders are mobilizing before upgrading their information systems. Setting up international organizations specifically dedicated to interoperability gives rise to recommendations that are taken seriously, such as those of the United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT) (UNECE, 2019).

Moreover, the environmental issues linked to maritime transport along hinterlands and logistics corridors concern both physical and immaterial flows. By improving the fluidity of these flows, blockchain technologies help to respond to this environmental emergency.

Citizens' heightened environmental awareness has also led companies to seek to lower their carbon footprint and to increase the traceability of transported goods, whether they are industrial or food items. It is thus becoming crucial to stay a step ahead with regard to processes that give consumers real confidence in the traceability of the products they buy. Falsifications revealed by financial, industrial, and food scandals have created a need for new traceability tools that will rebuild the public's trust (Wu et al., 2022).

Good management of port security also requires the implementation of new tools to monitor the traceability of port goods transported or stored in ports or in industries to avoid the kinds of disasters that occurred at the beginning of the twenty-first century (such as the Lubrizol factory fire in Rouen or the Beirut port explosions).

All these questions, which refer to industrial, environmental, and societal issues, lead to work in the fields of innovation to redefine digital trust at the heart of corridor fluidity, traceability, and security. Blockchain technologies aim to provide highly effective solutions in this context. This chapter explains how they work and the use cases for the sustainable development of logistics corridors, as well as examining the current constraints and limits of these technologies.

Blockchain

In 2007, the world plunged into the "subprime crisis," a financial crisis that caused major instabilities in the financial world associated with an unprecedented mistrust of the banking and monetary system. In October 2008, an unknown individual or group operating under the pseudonym "Satoshi Nakamoto" published a white paper proposing a secure, notarized, decentralized cryptocurrency system on a peer-to-peer network (Nakamoto, 2008). It was Bitcoin that revolutionized the way digital money is made. In January 2009, the genesis block of the Bitcoin public blockchain was created, allowing the first transaction of ten Bitcoins to take place on 12 January between Satoshi Nakamoto and Hal Finney.

All the basics of blockchain technology are present in Bitcoin, and we will explain more about them later in the chapter. In 2014, the introduction of smart contracts made it possible for blockchain technology to handle more sophisticated transactions, as we will also explore later.

Generals concepts

Blockchain technology is a set of pre-existing technologies which, when cleverly assembled, produce a result capable of offering strong and disruptive solutions.

Blockchain or distributed ledger technologies

A blockchain can be defined as a decentralized digital ledger that allows transactions to be recorded – or rather, notarized – in an unfalsifiable manner.

The term notarization is relevant because the blockchain brings a notion of trust to transactions in the same way as a notary does. When you need to buy a property, going through a notary puts you in a relationship of trust with the seller. Without a notary, you might wonder whether the seller might sell the property a second time, and you run the risk of one day being confronted by someone claiming to be the owner of the property you believe yourself to own. Using a notary eliminates these doubts because the notary's register system offers you protection against a double sale.

Blockchain technology provides the same service through a digital ledger whose security and forgery-proof properties are presented next. The three major properties of a blockchain are therefore:

- Security – it is almost impossible to corrupt data thanks to a double security system based on encrypted chaining and replication of data on a network.

- The absence of a trusted third party – it is the set of technologies and a network of actors that operate this trust.
- Transparency – transparency characterizes public blockchains in particular, where transactions can be consulted publicly. However, it should be noted that although the record of transactions is clearly visible, these transactions may be encrypted and therefore difficult or even impossible to decipher if one does not have the necessary keys to do so.

Double security of the blockchain

In this section, we explain how blockchain technologies make data secure and impossible to forge.

A blockchain described as a digital ledger in a digital data structure. This data structure is composed of chained blocks of information, hence its name.

The transactions to be recorded in a blockchain contain a certain amount of information. For example for a blockchain dedicated to digital currency transactions such as Bitcoin, the following information must be mentioned: the amount to be transferred, the debtor, and the recipient of the financial transaction. A block of a blockchain contains several transactions that are grouped together with a record date.

When a new block is going to be recorded in the blockchain after a validation stage (we will return to this in the next section), a final piece of information known as a "hash" is included in this block – namely, a digital fingerprint of the last recorded block. This fingerprint is what allows chaining to be carried out between the various blocks, thus permitting users to browse all the information stored in the blockchain (see Figure 12.1). This digital fingerprinting or hashing mechanism is a well-known process which, thanks to a few kilobytes, makes it possible to identify the content of information of any size. This mechanism is used, for example, when you want to check that a software update downloaded from the internet has not been corrupted: The hash mechanism is used on the downloaded update and compared with the signature that the software publisher advertises as valid. If the smallest byte of data has been maliciously modified in this update, it will produce a hash that is completely different from the original.

In the same vein, if a malicious operation attempts to modify information about a transaction in a blockchain, the hash of the block containing that transaction is also altered, causing the blockchain to fall apart and the malware to be discovered immediately.

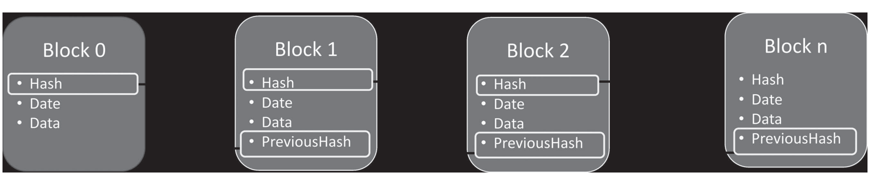

Figure 12.1 Chaining mechanisms in blockchains.

Furthermore, an inherent property of blockchain technologies is the fact that they are based on a peer-to-peer network. This means that the digital register is duplicated on all of the network nodes that will serve to validate this blockchain (we speak of validator nodes). As a result, any attempt to defraud and modify the blockchain on one of the network's nodes will be automatically detected because the modified register on this node will differ from the registers on the other nodes.

This double level of security – achieved through chaining and duplicating the digital register on network nodes – offers a very high level of protection against tampering or in any case a higher level than that offered by any other information system designed to date.

This reliable guarantee introduces constraints which have an operating cost. Indeed, since no modification can be made unilaterally on a single network node, it is sometimes necessary to make modifications to the blockchain in a coordinated manner between all the nodes, in particular when new transactions need to be notarized and new blocks containing these new transactions added. This coordination requires a consensus, which will be explored in the next section.

An example of an anchor to ensure the traceability and security of a freight transport chain as it passes through a logistics corridor

Before continuing with the explanation of the different techniques and processes used to implement blockchain solutions, we will illustrate the merit of using blockchain for logistics corridors. In Figure 12.2, we illustrate the benefit of using blockchain to secure and trace a commodity's entire transport chain from its arrival at the port to its delivery to the recipient, via a logistics corridor.

The aim is therefore to securely anchor relevant and useful information for tracing goods during transport. One of the key points in the development of the blockchain-based secure information system is to identify critical events and to derive from them the information that must be anchored in the blockchain. In our case, it is generally necessary to anchor the following critical points: the arrival of a container at the port; the movements of the container via geolocation devices; the exit of the container from the port; the various stages of multimodal routing of the container by river, rail, or road; and its arrival at the recipient.

In the event of a dispute between operators, for example if a failure occurs, a legal authority can consult the entries in the blockchain. The processes used for anchorages have to be validated before they can be used as legal evidence.

Validation consensus

A validation consensus is a process that allows all the nodes contributing to the blockchain to agree to validate and register a new block of transactions in all the copies of the blockchain that each node owns.

This raises a few initial questions: Who are these validators? What is their interest in contributing to the proper functioning of the blockchain, which requires a considerable amount of work on their part?

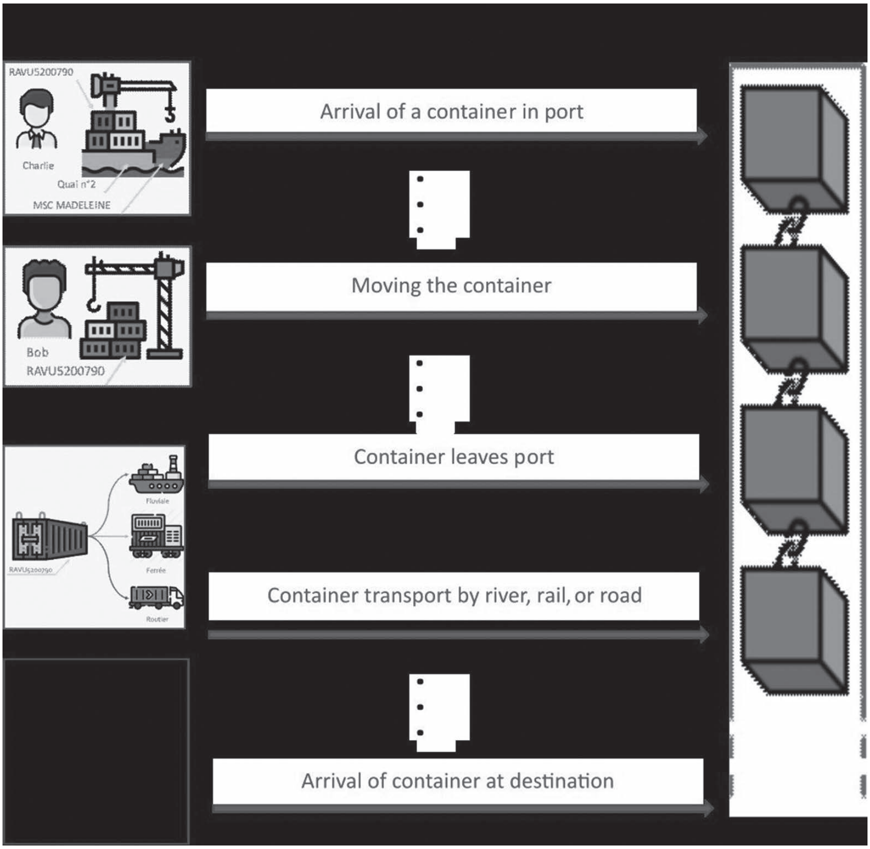

Figure 12.2 Blockchain-anchored process to secure and trace the transport of goods along a logistics corridor.

In public blockchains such as Bitcoin or Ethereum (which will be discussed later in the chapter), membership of the blockchain and its collective validation system is open to anyone by downloading a software package and connecting via the Ethernet network to sub-networks dedicated to these blockchains.

The two public blockchains mentioned earlier are currently (in June 2022) recording a wide variety of transactions involving a multitude of actors. These transactions and these actors are not related to each other. The validation mechanism is completely unrelated to the motivations behind these transactions; it ensures a simple mechanical operation of the validation processes that must respect technical checks. The validators who adhere to a blockchain validation mechanism have no connection with the motivations of the transactions.

For the two public blockchains mentioned earlier, a validation operation currently requires complicated calculations to be carried out, which demand high computational power. It is therefore necessary for validators to be rewarded for the resources they make available to the blockchain to maintain its validation mechanism.

To do this, the transaction validation mechanism must offer validators some form of reward. One such consensus mechanism, called proof of work, requires validators (known as miners) to solve a complicated cryptographic problem. The proof-of-work consensus used for Bitcoin, for example, is called the Hashcash algorithm and consists of adding a sequence (called a nonce) to the block to be anchored so that the hash of the block begins with an imposed numerical sequence. It is then necessary to explore and test a considerable number of sequences to be added to the block to solve this problem. This process is computationally intensive, but the solution can be verified very easily. The first validator to solve this cryptographic problem submits its solution and the validation of the transactions to the network, which its members can then easily verify. If this verification is correct, the validator who originated it is paid in cryptocurrency. The proof of work favours a selection of the validator based on computing power rather than on a choice of vote representativeness, which selects a priori a validator that can be more easily corrupted by an individual capable of granting himself many addresses (Nakamoto, 2008).

Validators need to be paid to operate a blockchain, and the use of cryptocurrencies is essential. These cryptocurrencies are highly volatile and generate uncontrollable speculative appetites. Their large-scale deployment could cause stock market fluctuations that may worry certain organizations or countries.

In this mechanism, all the validators in the network work in parallel and compete to obtain this remuneration. The energy cost of the computing power involved can become considerable. In January 2022, the operation of Bitcoin consumed as much electricity as a country such as Finland. The Ethereum blockchain still operates today (in June 2022) using a proof-of-work consensus, but over the past few years, its development teams have been announcing a long-awaited transition to another consensus method called proof of stake.

Proof of stake does not require validators to seek to solve a cryptographic problem simultaneously. Instead, each validator has a cryptocurrency capital that serves as a stake to obtain the right to validate a block. The system then selects the validator according to its wagering capacity. Only the selected validator validates the block, and it does not have to solve any cryptographic problems. If the selected validator's validation is correct and approved by the network, the validator's betting capacity is increased, otherwise it is decreased. The cost of validation is almost zero compared to that of the proof-of-work mechanism, but it requires precautions in a public blockchain to prevent validators from holding a majority position that could be a source of malicious actions.

Blockchain typology and governance

To conclude the presentation of these concepts, we will discuss an important point that arises when searching for concrete blockchain solutions. We have so far based the concepts presented on public blockchains, with particular reference to Bitcoin and Ethereum. These blockchains are open to public participation, and all the validators who have chosen to join them hold the validation mechanism via the consensus previously presented. Transactions (possibly encrypted) are visible and publicly recorded in the blockchain.

This mode of operation is not necessarily suitable for certain transactions. Applications that concern sensitive operations with regard to the security of people and goods would want to avoid showing an overactivity of transactions (even encrypted ones), since they may contain highly important information. For example if a port wished to make the tracking of hazardous goods containers more efficient by recording their location in a public blockchain, it would not be desirable for this information to be accessible to everyone, especially to malicious organizations that could exploit it for terrorist purposes.

Moreover, the replacement of the trusted third party behind a public blockchain by a decentralized network and consensus operation does not necessarily make legal sense. For example a port authority that wants to trace transactions in its domain of action will remain liable for system malfunctions or malicious acts by its participants, even though we have seen that it is difficult to commit malicious acts because of the system's high level of security.

The Hyperledger blockchain is an open and distributed enterprise development platform that favours the concept of a private blockchain. In this concept, an operator will deploy its own blockchain, independent of public blockchains such as Bitcoin and Ethereum. This operator therefore controls the system (a port authority for example) and will only make it accessible to a group of invited collaborators. These collaborators will then be asked to form the network of validators, under its control. The visibility of transactions is therefore reserved for these trusted participants who generally have an interest in the blockchain solution developed (traceability or fluidity of flows, for example) and are therefore ready to contribute to the validation of blocks without needing to be paid. The proof of stakes also becomes a consensus that is satisfactory for this network of private validators.

Another approach is called Consortium blockchain where a few actors have a common interest in securing and tracking transactions. Three copyright management companies in the music sector – SACEM, ASCAP, and PRS for Music – have launched an experiment to manage copyright via a Hyperledger-based blockchain in order to meet the challenges of possible conflicting identifiers for the same work across multiple rightsholders.

Smart contract

In 2014, with the creation of the Ethereum blockchain (Buterin, 2014), the notion of smart contracts also appeared. They are designed to manage transactions other than simple transfers of value (digital currency for example) between two contractors. The transaction is translated by programmes that automate the actions required in a contract. These computerized transaction protocols have been named smart contracts and are also stored on the blockchain, which guarantees their immutability. They often refer to conditional executions of the type "IF condition THEN instruction1 ELSE instruction2." For example if one were to build a contract for flight delay insurance, then one could automate the partial or full refund of a plane ticket when the plane arrives late.

Application of blockchain to port and maritime logistics

In recent years, blockchain technology has been used increasingly in the field of maritime and port logistics. There are a number of applications in this field: Sku-chain, Provenance, Chain of Things, Waves, etc. It must be said that in this field, this technology offers undeniable advantages for the modernization and fluidity of global logistics chains.

The use of a secure digital register can make a significant contribution to the dematerialization and elimination of hand-signed documents. Currently, it is still common practice to use paper trade documents in the exchange of goods. This can lead to delays when the authorized person is not available to sign a document.

Because of the near-impossibility of falsifying transactions carried out on the blockchain, it can contribute, together with the recording of operations carried out in the physical world, to a better traceability of goods as well as to the accountability of the various actors in the global supply chain. It is easy to set up monitoring systems for transport conditions using connected objects that automatically record their data in a blockchain. For example the temperature of a refrigerated container can be monitored, and it is possible to check whether the cold chain has been respected or not thanks to a temperature sensor that has become unforgeable.

One area where traceability and monitoring of transport conditions is important is in the management of dangerous goods. Dangerous goods containers are subject to standards that require 13 documents to be kept throughout the container's stay in the port area. These documents are declarations as well as container-tracking records. Thus, this field could strongly benefit from the contribution of the blockchain (Simon et al., 2020; Simon et al., 2021; Abdallah et al., 2022a, 2022b).

In the field of logistics, especially freight transport, carriers must be able to present a document called a consignment note (CMR). It must be drawn up before the execution of a transport contract and formalizes the transport contract between a sender, a carrier, and a consignee. The dematerialization of these documents represents a crucial challenge for the fluidity of logistics flows. Blockchain also appears to be a solution for securing and streamlining document exchanges. It makes it possible to trace the movement of goods and to have legal proof should there be a dispute over responsibility in the event of an incident during the transportation of goods (Garbaccio et al., 2021).

In recent years, several attempts have been made to make massive datasets available. These include open data platforms, mainly at the institutional level. Despite the growing interest in these data platforms, which can be used to develop new services, there are obstacles at the business level. This data can be very competitive and represent an essential asset for companies. They must therefore be able to keep control of their data and not reveal it to actors who could use it to compete with them or for malicious purposes. It is therefore necessary to provide these potential data providers with the means to maintain control over access to their data and to decide who can access it outside the company. One solution is to implement secure consent management using blockchain technology (Goint et al., 2021a, 2021b). The aim of these new data platforms is to make data available that can be reused to build new services for users in the context of smart territories.

Conclusion

Blockchain technologies and smart contracts offer powerful solutions to the challenges of smart ports and the development of international trade by securing these processes and making them digitally trustworthy. They are probably the key to significantly improving the fluidity of transactions not only at the port level but also at the level of logistics corridors. Blockchain solutions are a clever combination of different mechanisms and technologies that have already been mature for some time. However, these solutions are still subject to barriers that prevent their large-scale deployment. The first barrier is the energy cost and, associated with this cost, the low transaction rates that result from the consensus mechanism between the nodes of the support network, particularly in the context of the proof-of-work mechanism. Furthermore, the development of blockchain solutions requires a reflection on the relevance of the governance model corresponding to public or private blockchain models. Alternatives to proof of work, such as proof of stake, are already operational on private blockchain platforms (e.g. Hyperledger) where all the validating nodes constitute an identified ecosystem. These alternatives are still being tested for public blockchains in order to preserve the quality of the consensus mechanisms and to avoid malicious takeovers. This development has been announced and postponed several times for the Ethereum blockchain. The most ambitious ports and corridors for the development of smart ports are investing heavily in blockchain technology and understand the challenges of establishing reliable solutions throughout the port industry in the name of this breakthrough, which would constitute an essential element in the evolution of port information systems. The use of blockchain technologies to provide legal proof of contracts and transactions remains a hotly debated subject; the Catalyse project supported by the GIS Institut pour une logistique intelligente en Vallée de Seine (Institute for Smart Logistics in the Seine Valley) has proposed a development in the concept of smart contracts in order to include elements that would enable the proper execution of contracts to be verified and validated on a legal level.

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13 Responding to navigation challenges on the St. Lawrence River corridor

The role of information technologies

Brian Slack, Claude Comtois and Philippe de Champlain

Introduction

Since the European colonization of eastern North America in the seventeenth century, the St. Lawrence River has served as a corridor between the heart of the continent and the Atlantic Ocean. Today, it provides maritime access between world markets and over 100 million people located along the river itself and along the shores of the Great Lakes of Canada and the United States. While large sections of the corridor have always provided unimpeded access, linking these sections together has required major improvements, especially the bypassing of rapids. In this chapter, the focus is on the St. Lawrence River itself. It explores two long-lasting navigation problems that have been overcome to some degree: water depths and ice, as well as a new challenge of avoiding collisions between ships and whales. Instead of relying on large-scale capital investment solutions as before, new information technologies such as digitalization are now being adopted.

Finally, the applications of information technologies to shipping problems are examined. For some, these applications are seen as establishing a digital waterway that will serve as a precursor to the introduction of automated shipping. What is evident is that the problems and possible solutions differ because of the diversity of conditions experienced across the 1,200 km-long river. The scale of the corridor is vast, and while we may be able to implement digital solutions in parts of the river, it has not been possible to create a uniform set of technologies that would encompass the area from Lake Ontario to the Gulf of St. Lawrence.

The St. Lawrence River and its challenges

The features of the St. Lawrence River vary considerably over its 1,200 km. Starting as a fully-fledged river as it drains Lake Ontario at an elevation of 245 m, it falls to 7 m above sea level at Montreal through a series of rapids and is then joined by several large tributaries (Ottawa, Richelieu, and St. Maurice Rivers) as it flows to where tidal influences are felt in Quebec City. It then broadens progressively as an estuary as far as the Gaspé Peninsula, before forming the Gulf of St. Lawrence, an

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inland sea, which opens out into the Atlantic Ocean through two straits: Cabot and Belle Isle (Figure 13.1).

Given the scale and diversity of the corridor, it is inevitable that the challenges relevant to navigation and to trade and commerce differ from one part of the river to another. Two natural conditions of the river have presented enduring challenges. First, variable water depths and the prevalence of shoals in the river and estuary sections present navigation hazards. A series of rapids between Lake Ontario and Montreal were a major natural barrier to shipping because the river falls by 238 m. Second, ice conditions represent a significant seasonal challenge to navigation for approximately three months of each year. The challenges presented by ice are different in the Gulf – where winds move ice floes which result in large open water areas – compared to in the river sections, where blockages and ice jams prevent passage.

There have been ongoing efforts to address these challenges for over 300 years, but despite significant progress, many of the same problems persist today. However, thanks to the development of new technologies involving digitalization, electronic and satellite monitoring, and displays in real time, the field of navigation is currently being revolutionized. These applications aim to improve the safety and security of shipping (Jović et al., 2022). A wide range of systems have been placed into categories by the International Hydrographic Organization (IHO). Examples include S-122, maritime protected areas; S-142, weather overlays; S-111, surface conditions; and S-101, electronic navigation charts. For the IHO, these categories must be seamlessly integrated to provide a uniform information base referred to as S-100 (IHO, 2022).

Navigation and water depths

In the more confined waters of the estuary and river sections of the St. Lawrence River, shoals and shifting channels have long been recognized as a problem. The provision of navigation charts and the use of pilots began in the late 1600s (Castonguay, 2016). Subsequent refinements to instrumentation made charts more accurate, and the obligation to use qualified pilots made passage through the river up to Montreal much safer over the years. Capital investments in lighthouses and other navigation aids, such as buoys, further improved safety.

The most significant advancements came about through capital investments made in two different sections of the river between Quebec City and Lake Ontario. The first section comprises the river between Quebec City and Montreal in which there are a number of shallows, especially in Lake Saint-Pierre, where the river widens to 15 km. In 1856, the beginnings of a channel were dredged, leading to the present 11.3 m ship channel (Figure 13.2). In the second section are the series of rapids that lie between Montreal and Lake Ontario. In the 1820s, a set of canals was constructed around the rapids, culminating in the opening of the St. Lawrence Seaway in 1959. The Seaway was not simply a canal project, since it involved hydroelectric generation, regional economic development, and a means of controlling the level of Lake Ontario and the river discharge. In this chapter, the term “Seaway” applies to the canal systems between Montreal and Lake Ontario.

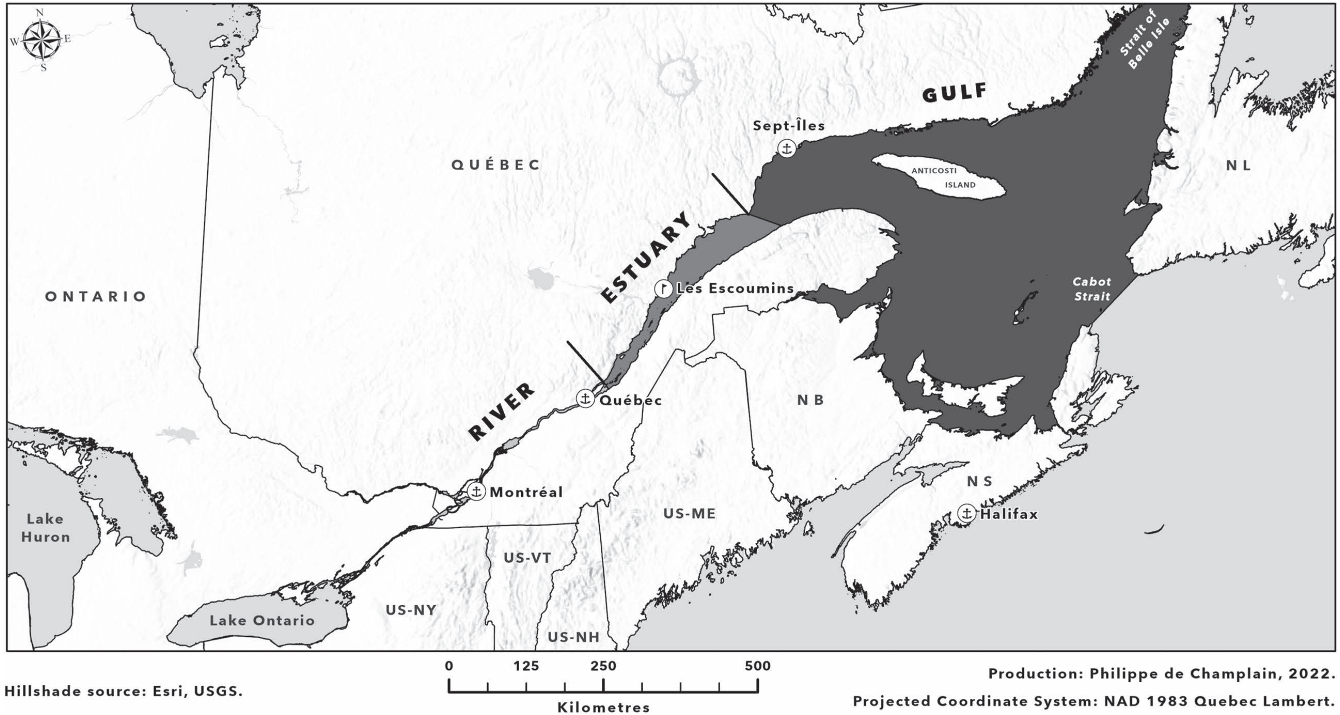

Figure 13.1 St. Lawrence River system.

Source: authors.

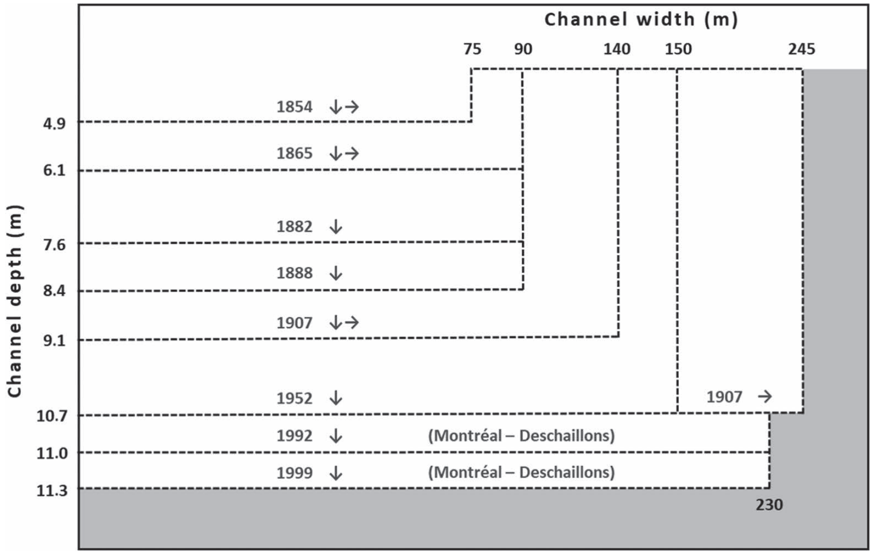

Figure 13.2 Evolution of channel depths in the St. Lawrence River.

By the beginning of the twenty-first century, ports around the world had begun to increase the depths of their approach channels to between 13 and 15 m of water because of the increasing size of ships' draughts. The port of Montreal has not followed suit, in part because of the cost and social acceptability of dredging. However, the pressure put on the port to comply is not comparable with the pressure elsewhere, since Montreal is the only port of call for container vessels, and all containers on board ships are unloaded and loaded at the port. Montreal's shipping business can therefore be accommodated within the current channel. Today's main challenge for the port of Montreal is that its water levels are not always 11.3 m above chart datum due to variations in water discharge.

Even though the St. Lawrence River drains the Great Lakes with their enormous storage capacity, its flow varies from year to year, as well as seasonally, with high levels in the spring and low-water levels in the late summer and early autumn. Annual variations are cyclical with several years in sequence where below average flows occur.

As long as the ship channel provides 11.3 m of water above chart datum (the reported minimum low-water level measured), vessels can sail pass normally, but when river water levels fall below chart datum, their passage is impacted. The loss of guaranteed water depth forces ships to lighten their loads, which means a loss of revenue. Their carrying capacity is already reduced on this part of the river because fresh water is less buoyant than the sea. The immediate impact on the shipment of containers has been the imposition of $200 in surcharges per TEU by the container carriers to offset their loss of revenue. For the port authority, this is a major challenge to its reputation and its competitive market position (Comtois & Slack, 2015).

The Montreal Port Authority faces a conundrum. Most years, the present channel depth is adequate for all shipping activity. However, approximately one year in every six, the channel's water levels fall below chart datum for a few weeks. To continue with the historic solution of further dredging the channel – a costly undertaking that could have serious environmental consequences and likely provoke a great deal of social opposition – would require strong commercial justification. The port authority is therefore turning to digitalization for a solution.

Today, the availability of new and evolving information technologies provides options for how nautical data are managed, disseminated, and used. Digital technology gives data producers and users powerful tools to store, transmit, update, and view information about the marine environment. When coupled with automatic identification systems, tracking the position of vessels in real time allows for vessel movements to be recorded on electronic charts. The nautical charting world reflects these changes, and the use of Electronic Chart Display and Information Systems (ECDIS) is required for all ships built after 2009 by the International Maritime Organization.

Both federal and provincial governments have announced the goal of transforming the St. Lawrence River into a smart corridor. The Canadian Hydrographic Service has installed 13 gauges along the river between Montreal and Quebec City to monitor conditions in real time. These include the dynamic vertical condition of the water column and the state of the tides. Other sites provide observations on weather, including temperature, pressure, and wind. Furthermore, the vertical clearance of the three bridges between Quebec City is also measured in real time. These sources are now used by the harbour master of the port of Montreal to give shipping lines updates on water and weather conditions along the river, thus providing an accurate picture of the current state of navigation. Vessel loadings are thus able to reflect the actual capacities of vessels being loaded.

As useful as these data are for the terminal operators and shipping lines, they only provide information at the time of measuring. Given that the loadings of ships overseas destined for Montreal generally take place between 10 and 21 days before the ship enters the Montreal ship channel, the channel's conditions may have changed significantly before arrival. While a vessel loading in Montreal can make the most of water columns above 11.3 m and increase cargo loadings, this is not possible for arrivals. Those loading overseas not only miss opportunities to increase loadings when water columns are higher than 11.3 m, but also they may arrive when the water levels are abnormally low. As a result, the port authority has been trying to predict water levels based on current observations. Two prediction models have been developed – one by the Canadian Coast Guard and the other by the St. Lawrence Global Observatory – the results of which are published daily by the control centre of the port of Montreal and distributed to the shipping community (Montreal Port Authority, 2022). Consultant engineers have been employed to improve the accuracy of predictions, but accuracy currently declines sharply after four to six days.

There is one further aspect to discuss, relating to low water: its relationship with the outflow of Lake Ontario. It is estimated that 90% of the water at the port of Montreal is made up of outflow from Lake Ontario. Since the opening of the St. Lawrence Seaway in 1959, the flow is controlled at the Moses-Saunders Dam in New York State and regulated by the protocols established by the International Joint Commission (IJC). These protocols include maintaining water levels in Lake Ontario, regulating outflows to maximize waterpower generation, and managing outflows below the dam.

Since 1963, the water level of Lake Ontario has remained remarkably stable, and there have been no periods where levels have fallen below 1 standard deviation from the mean. In contrast, between 1998 and 2012, the port of Montreal experienced the longest period of below average water levels in 100 years, and in 8 of those years, levels fell below chart datum for several weeks. Consequently, the IJC reviewed the water flow protocols and in 2014 produced a set of new objectives that included the relaxation of measures to manage water levels in Lake Ontario and allow more flexibility in flow management (IJC, 2014). One example of this less rigid approach was to facilitate short "river" diversions – namely, occasional increases in flow to address low water conditions at the port of Montreal. Whether these diversions will provide any benefit to the port of Montreal in future instances of water levels falling below chart datum remains to be seen, but it is estimated that a lowering of the level of Lake Ontario by 1 cm increases the water level at Montreal by 17 cm.

Ice conditions

Ice is present on the St. Lawrence River for many months of the year. Ice coverage is variable, with the Gulf of St. Lawrence maintaining some open water most winters. Many large ports such as Sept-Îles remain open all year. Paradoxically, the most serious ice conditions occur in the most southerly sections of the river above Quebec City. Ice jams are most likely to form here and cause blockages during cold periods when the open water freezes and the river flow velocity is not strong enough to transport it away. Up until the 1960s, the port of Montreal remained closed to navigation from late December to late March, and this is still the case for the Seaway during the same period.

Early attempts to intervene in ice conditions began with the use of icebreakers, the first of which entered service in 1928 to prevent shore flooding caused by ice jams. In the 1950s, the acquisition of new and heavier icebreakers made this task easier, at which point the shipping industry took interest in them as a means of facilitating navigation. In 1966, the Federal Department of Transport undertook an ice control project in conjunction with the creation of new islands being built for Expo 67 in Montreal. The focus was on Lake Saint-Pierre, where the weak current generated the largest ice jams on the river. Four islands north of the channel were built to hold back shore-based ice, and four ice booms were built in the lake. The four islands were found to be ineffective and were destroyed in 1984 to be replaced by five new islands, south of the channel. In the 1990s, these were replaced by 20 ice booms built in the lake and in the river above Lake Saint-Pierre.

All of these capital improvements led to the establishment of a regular winter service to Montreal, with the first ship arriving in 1969. Winter navigation was also made possible by the increasing power of ship engines and the required ice-reinforced hulls of commercial shipping. The booms did not always prevent jams, and there were a number of winters in which it was necessary to use icebreakers. In 1993, an ice jam interrupted navigation for 30 days, with severe consequences on supply chains. Evaluations of the causes revealed that it was the absence of real-time data, which prevented any chance of early intervention by the Canadian Coast Guard. This led to the development and deployment of the St. Lawrence River Ice Manager in 1998, an integrated monitoring system for ice (concentration, speed, thickness, and flow rate), water (elevation and temperature), and wind (speed and direction). The software displays current ice conditions based on the most recent observations, along with a graphic display of present and future ice trends. A decision support system gives ice managers the ability to implement preventative measures. Measurements using radar, sonar, cameras, and other sensors are obtained from 15 positions within the lake and at the entry and exit points (Dumont et al., 2001) (Figure 13.3).

The St. Lawrence River Ice Manager has been reasonably successful, but serious ice jams were encountered in the winter of 2018–2019, which led to a reassessment (Scalabrini & Morse, 2021). Recommendations included improving the reliability of radar equipment, the possible use of drones, and refinements to some of the booms.

As mentioned earlier, the Seaway remains closed to shipping for up to three months. Both the canals that bypass the rapids and potential damage to lock gates are cited as problems. This means that regular container services are difficult to implement, while bulk shipping has always been able to adapt to the closure thanks to the stockpiling of products above and below the Seaway.

In the Gulf and below Les Escoumins in the estuary, ice conditions are different to those in the upstream sections, partly because of tides and salinity, but also due to the sheer size of these sections, where winds and currents help disperse ice. It is simply impossible to replicate the monitoring system employed between Montreal and Quebec City, and thus monitoring ice conditions relies mainly on airborne surveys using imaging radar and radiation thermometers, as well as visible observations by trained personnel. Additional observations by shipboard personnel on snow depths, ice behaviour, and water temperatures, as well as shore-based observations, are passed on to the Canadian Ice Service where daily charts are prepared that display ice concentration and ice types. Satellite imagery based on RADARSAT and Moderate Resolution Imaging Spectroradiometer (MODIS) composites are also made available on a weekly basis.

New challenges: interactions with cetaceans

The St. Lawrence River possesses a very important marine ecosystem, including mammals such as seals and various types of whales, especially in the estuary and Gulf sections. Some cetaceans, such as beluga whales, are year-round residents,

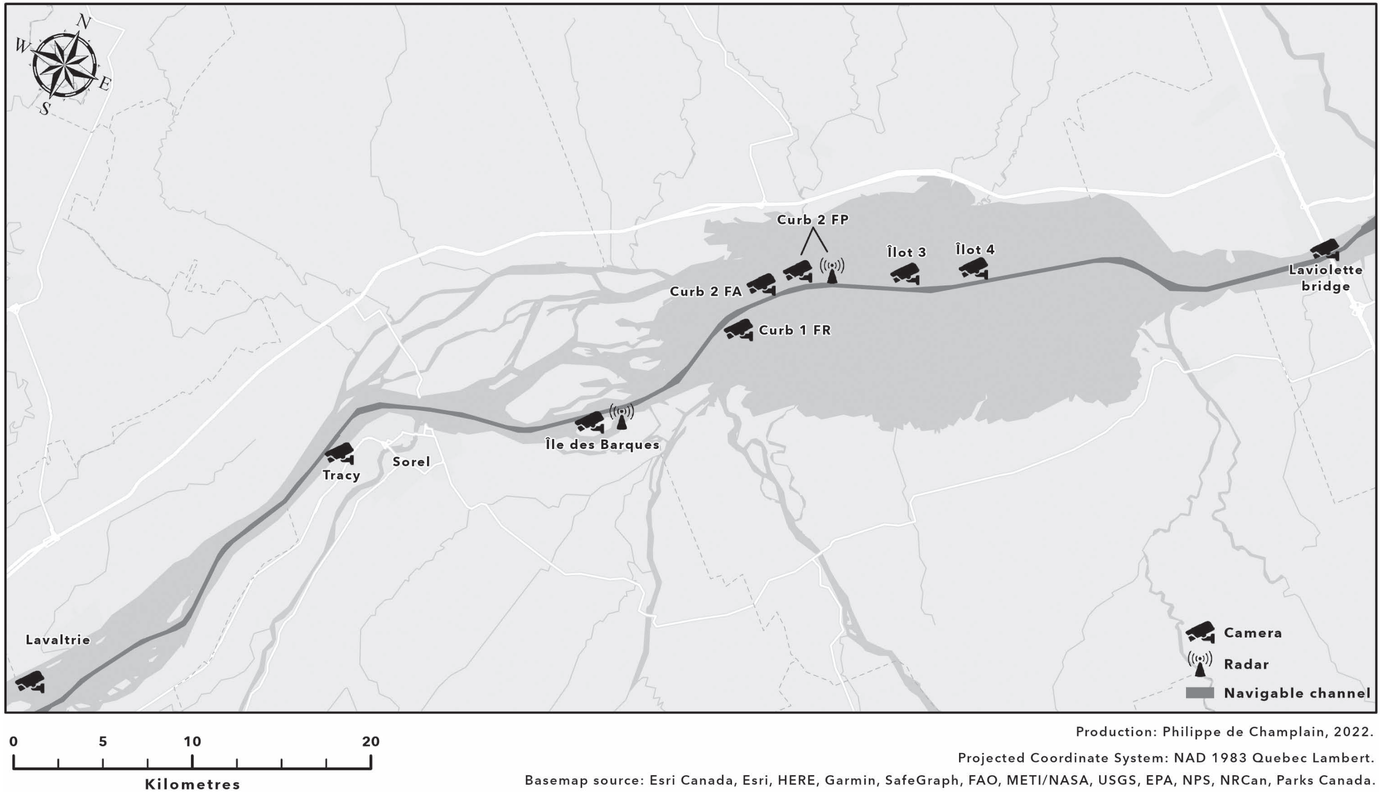

Figure 13.3 Main ice monitoring sites in Lake Saint-Pierre.

but there is a wide range of other species, including the largest (the blue whale), which are migratory. Vessel contact with whales became an issue in 2010, when there were reports of injuries to fin whales in the estuary. In 2016, a no-go area was established, and slow-down areas were defined, where vessel speeds were restricted to below 11.3 km. This has proved to be successful, and the speed restrictions are being observed, mainly because in these zones the ships are required to use pilots.

By 2015, it was becoming clear that incidents with North Atlantic right whales were increasing in the Gulf, with fatalities caused by collisions with ships and entanglements in fishing gear. This species is slow moving, does not have an innate reaction to avoid noise, and is easily entangled in fishing gear. It is an endangered species with a population of only 400 right whales remaining (Pettis et al., 2022). In winter, it inhabits the Caribbean and then moves up the East Coast of the United States as far as Maine in the spring and summer. In the United States, two zones in New England and along the coasts of Florida and Georgia have been established where ship speeds are restricted to 10 km, but the sheer number of ships has made it difficult to monitor and control.

Since 2015, restrictions on vessel movements and fishing have been put in place in certain zones. Modifications involving zones with different requirements have been established, along with speed limits in the main shipping lanes when whales have been sighted (Figure 13.4). In static zones, speed limits are maintained for the

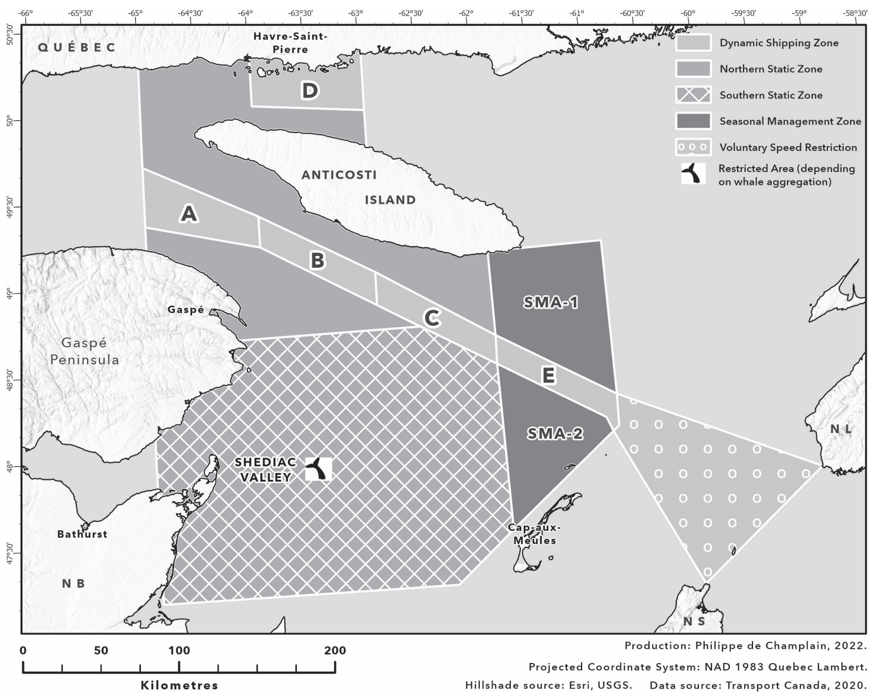

Figure 13.4 Shipping control zones in the Gulf of St. Lawrence.

full designated time period, while in dynamic zones, the duration of speed limits varies depending on whale sightings.

Pinpointing the exact location of the whales is not an easy task, and early surveys had to rely on traditional means, such as vessel reports and aerial photography from regular reconnaissance flights. More recently, a total of eight Viking Buoys, developed by a research centre in Rimouski, Quebec, have been positioned in the estuary and Gulf. Their original purpose was to record water conditions, but they are now equipped with acoustic sensors to detect right whale upcalls to indicate their presence. Measuring vessel speed compliance is achieved by monitoring ships' automatic identification systems, which broadcast vessel location, identity, course, and speed. Only six ships were reported for violations in 2019.

Conclusion

The St. Lawrence River represents an important corridor for marine traffic. Realizing its potential has been difficult because of natural conditions that have impeded safe passage. Over the years, these obstacles have been overcome to some extent by engineering solutions, but issues with safe navigation as a result of varying water depths and ice persist. Information technologies are being implemented to address these problems. The evidence presented here indicates that the ability to provide accurate information on the conditions of the ship channel in the upstream portions of the river benefits shipping, and that monitoring ice distributions and formation not only assists navigation but also facilitates action by the Coast Guard to prevent serious ice jams.

This study reveals that the nature of the problems of water depths and ice varies considerably between different sections of the corridor and therefore requires different technological solutions. The St. Lawrence River corridor is simply too extensive to permit uniform solutions. The power of digitalization is based on its ability to measure elements in real time, but examples presented here show that predicting changes from digital observations is difficult. Short-term trends over a few days may be possible, but longer-term forecasting is often inaccurate, as is the case for meteorology.

Is the St. Lawrence River a smart corridor? Although information technologies are being utilized, they are not yet capable of providing the level of sophistication that would be required to offer automated shipping. What is clear is that progress is making shipping safer, which is by no means an inconsequential result.

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14 Simulation tools for the flows of goods in the Seine corridor using a multimodal network

Julius Bañgate, Dominique Fournier, Éric Sanlaville and Thibaut Démare

Introduction

In order to anticipate the impact of multimodal logistics transport strategies, it is necessary to explore multiple scenarios. With this objective in mind, the presented work proposes a complex system approach by using multi-agent modelling and simulation. A similar approach is discussed in Davidsson et al. (2005) and has been implemented in the TAPAS and FAME agent-based models (Holmgren et al., 2012; Samimi et al., 2014). However, Tavasszy et al. (2012) have highlighted the limited nature of these models: they mostly evolve on a monthly or even yearly basis for each step. In our approach, GAMA was used in formalizing the model, particularly in defining the agents and their behaviours using GAML code (Taillandier et al., 2018). Some simple behavioural rules, combined with the use of spatial data and a delicate balance in the use of parameters, generated the dynamic and complex multi-actor interactions within the logistics network (Démare et al., 2019a). The tool that was developed can be used to study many different territories and types of traffic. In this chapter, we present two case studies within the Seine Valley territory. The first study takes into account all goods flows and illustrates how the tool may be used to anticipate, for instance, the impact of the Seine–Nord Europe Canal. The second one examines a specific sector and shows the possible impact of using short sea shipping on import flows.

The model

The approach can be used for any logistic territory. However, an accurate and realistic simulation necessitates real geographic data consisting of the location of actors and the transportation network (road, river, and maritime). The model was designed to reflect the dynamics and interactions between different actors and stakeholders. These behaviours and interactions include (1) requesting replenishment of stocks; (2) routing vehicles from origin nodes to destination nodes; (3) transporting goods to the correct destinations using the appropriate mode of transport; (4) loading, unloading, aggregation, reallocation, or re-aggregation of

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goods in transshipment nodes (terminals); and (5) production of goods in factories using delivered parts.

Some choices are made in the model, such as the use of a replenishment policy in accordance with a given threshold, the choice of the nearest warehouse, and shortest path routing.

Data relating to requests for stocks and on the arrival and departure of stocks are recorded for each node. Goods transiting through each segment of the transportation network are also recorded for the analysis of flows.

The model can be used to investigate the role and impact of different strategies regarding choice of commercial partners, storage, transportation modes, and so on. Here, we focus on the latter, considering different modes, or a combination of modes, of the multimodal transportation network (road, river, maritime/short sea). Note that only a small proportion of the traffic actually uses the railway in the Seine Valley, and it is not taken into account in the two case studies (although our model can deal with this kind of flow). A simple diagram of the import flows within the implemented logistics network is shown in Figure 14.1. In this diagram, only the import flows towards the Seine Valley (mainly towards the Paris region), which pass through the ports of Le Havre or Antwerp, are included. The next subsection on stakeholders offers a description of the agents involved.

The stakeholders

There are many actors involved in any supply chain. The actors involved in import flows are listed next, with an emphasis on the automotive sector. These are also presented in Figure 14.1.

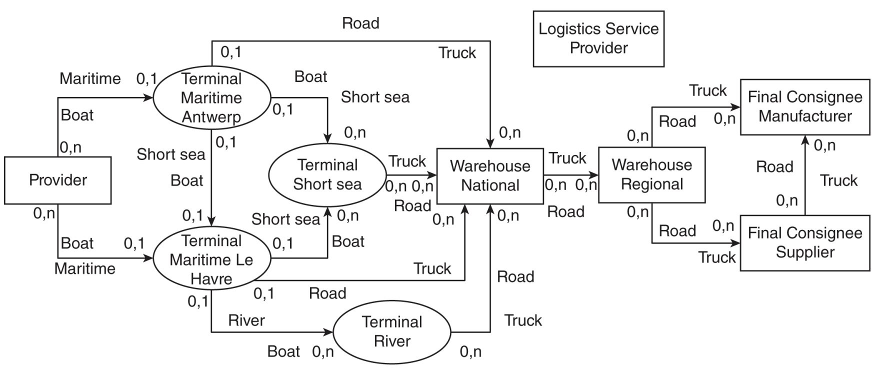

Figure 14.1 Import flows in the logistics network with all the actors/agents. Rectangles indicate supply chain actors. Ovals indicate transshipment points. The vehicles used to transport goods between the nodes are also indicated (truck, boat). The vehicles travel through their respective transport networks.

Final consignees

These are the actors who order the products circulating in the network.

(1) Assembly plants (manufacturers) – the final assembly of a product takes place in these factories. These products are intended for the domestic market or for export. The factory has to directly import its raw materials and the parts supplied by subcontractors or other manufacturers (original equipment manufacturers [OEM]). We assume that the manufacturer that owns the factory uses a logistics service provider.
(2) Subcontractors (suppliers) – this category includes national medium-sized or large suppliers, which are generally called equipment manufacturers in the automotive sector. The parts are manufactured in their own factories and then sent to the assembly plants. These suppliers also request stocks from international suppliers.

When considering the complete flow of goods, there is naturally a very large number of final consignees (several thousand, see next section), and manufacturers and suppliers are generally not distinguished from one another.

Logistics Service Provider (LSP)

Even when LSPs are internal to shippers, the model treats them as actors in their own right. They manage the transport of goods and therefore call on transport providers. These do not explicitly appear in the model, as they have no decision-making power. It would be more accurate to say that service providers act as the interface between shippers and carriers and are the only ones to negotiate with them. The transport providers use their own warehouses.

Warehouses

We distinguish between two levels of warehouses: local or regional and national. The former receive the goods from the latter, store them, and send them to the final consignees. The latter have greater capacity and play the role of hubs. They receive the goods from the terminals (maritime, short sea, and possibly river) and distribute stock to the requesting local warehouses.

Providers

The (foreign goods) providers are the main sources of imports to replenish the stocks of the national warehouses. Our study distinguishes between the providers that ship goods through Le Havre and those that ship through Antwerp. Maritime vessels transport the requested goods to the maritime terminals. From the maritime terminals, the goods can be transported in different ways. They are either directly transported to national warehouses by truck or sent to other transshipment nodes (short sea terminals, river terminals) before being transported to the national warehouses.

Terminals

The main maritime terminals in Antwerp and Le Havre receive imports directly from offshore suppliers (usually from Asia). After a possible storage phase, they are sent to national warehouses, a secondary maritime/short sea terminal (the eight medium-sized ports in Normandy), or one of the nine river terminals (on the Seine or the Oise). These intermediate terminals, located far from the main ports, then send the goods to the national warehouses. The river terminals in particular stretch further inland to allow imports to flow to final consignees in the Seine Valley (a large majority of which are in the Paris region).

Transportation network and vehicles

The transportation network provides the link between the different nodes of the supply chain. The shortest paths between nodes are used to transport goods. Different types of vehicles are used depending on the transportation mode or network. Trucks are used in land transport where it is necessary to travel further inland. River boats or barges can carry large volumes of stock on the river from Le Havre maritime terminals to the river terminals. Large vessels use the maritime and short sea routes to transport the largest volumes of stock between maritime ports and short sea ports/terminals.

Short presentation of simulation platform, GAMA

The two implementations of the model for the Seine Valley logistics corridor were developed using the GAMA agent-based modelling and simulation platform and were coded in GAML (Bañgate et al., 2021; Démare et al., 2019b). GAMA provides a powerful and simple modelling environment: (1) agent definition, agent behaviours, and the possible dynamic interactions; (2) optimized routing (e.g. shortest path, A* algorithm) between origin and destination in transportation networks; and (3) seamless integration of real geographic data into agent-based models. The user interface is shown in Figure 14.2.

Complete flow of goods: impact on Seine–Nord Europe Canal

In this section, we focus on the study of the complete flow of goods along the Seine corridor in France. This logistic system is centred on Paris and connected to the maritime ports of Le Havre and Antwerp. The entire road and river networks in this area have been implemented using real data. A foreign goods provider is established in each of the two ports, and both providers supply the system with overseas goods and simulate the existing competition between the two ports to deliver goods in this area (mainly to Paris). We calibrated the model according to real data when

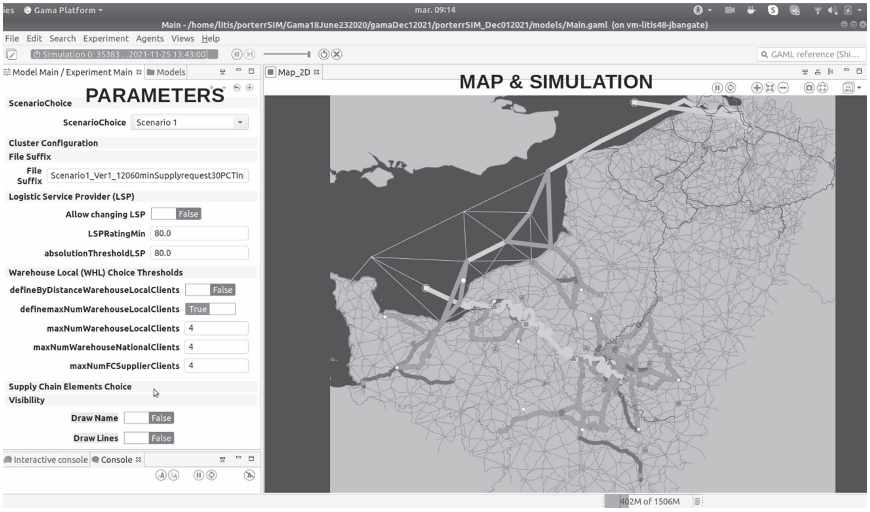

Figure 14.2 User interface: the parameters section of the interface enables the user to enter custom parameter values in order to conduct different experiments. The map and simulation section display the current simulation. In this window, it is also possible to zoom in and out of the map to focus on specific agents and their behaviours.

they were available (such as warehouse size, transportation network structures, average speeds, vehicles capacities). The values of the other parameters were fixed to reflect the current volume of traffic.

In particular, as long as the link between the northern European canals and the Oise River is missing, real data on traffic size in this area cannot be obtained. The expected completion date is now 2028. Therefore, the aim of our simulations is to study how the extension of the river network will impact the flow of goods on the Seine Axis in France.

Size (number of stakeholders)

Our simulations include around 3,000 warehouse agents and 500 final consignee agents. All of them have been randomly selected from the 7,700 wholesalers listed on the Sirene database.[1] The simulations also include 2,500 LSP agents from the official list of businesses specialized in goods' transportation. We designed two sets of simulations: one without the Seine–Nord Europe Canal and the other with this new link opened. We ran 16 simulations (8 with each scenario).

Impact of the Seine–Nord Europe Canal: numerical results

Figures 14.3 and 14.4 are screenshots of two different simulations configured with and without the Seine–Nord Europe Canal (SNEC) activated. Naturally, there is a

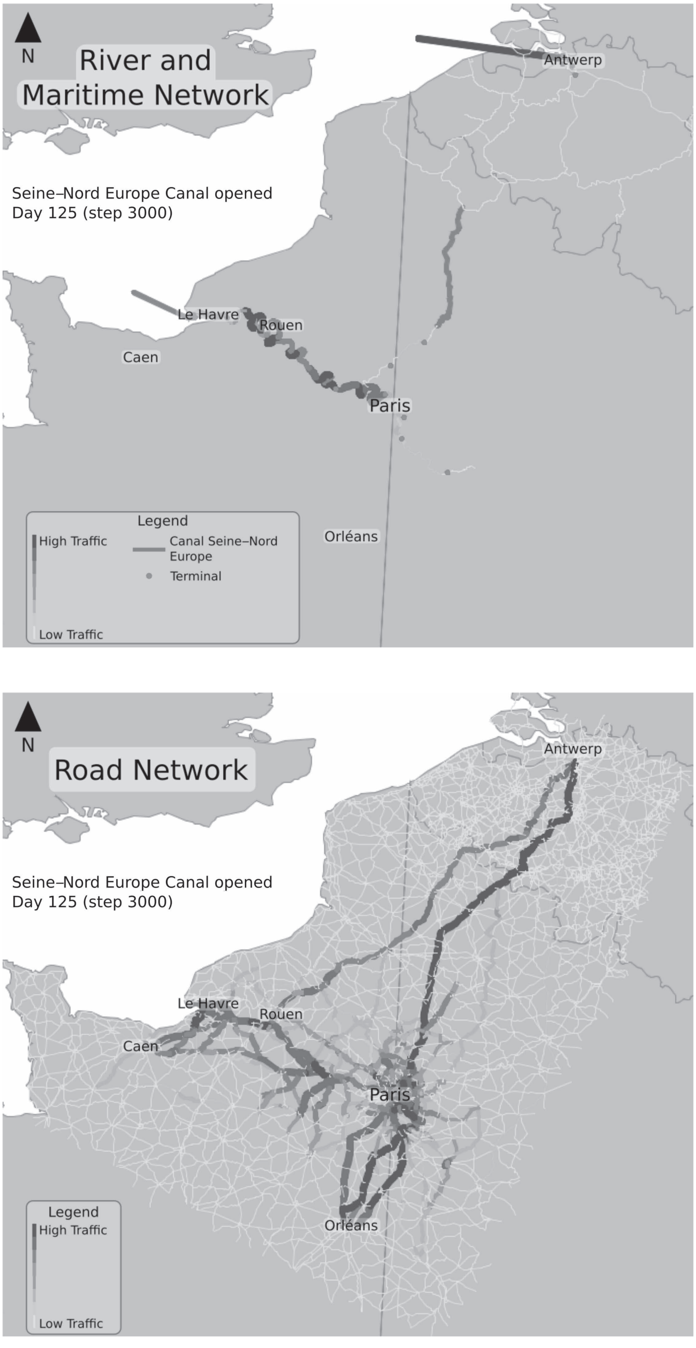

Figure 14.3 Screenshot: scenario 1 – flow of goods – the Seine–Nord Europe Canal is not open. (a) River traffic (b) road traffic.

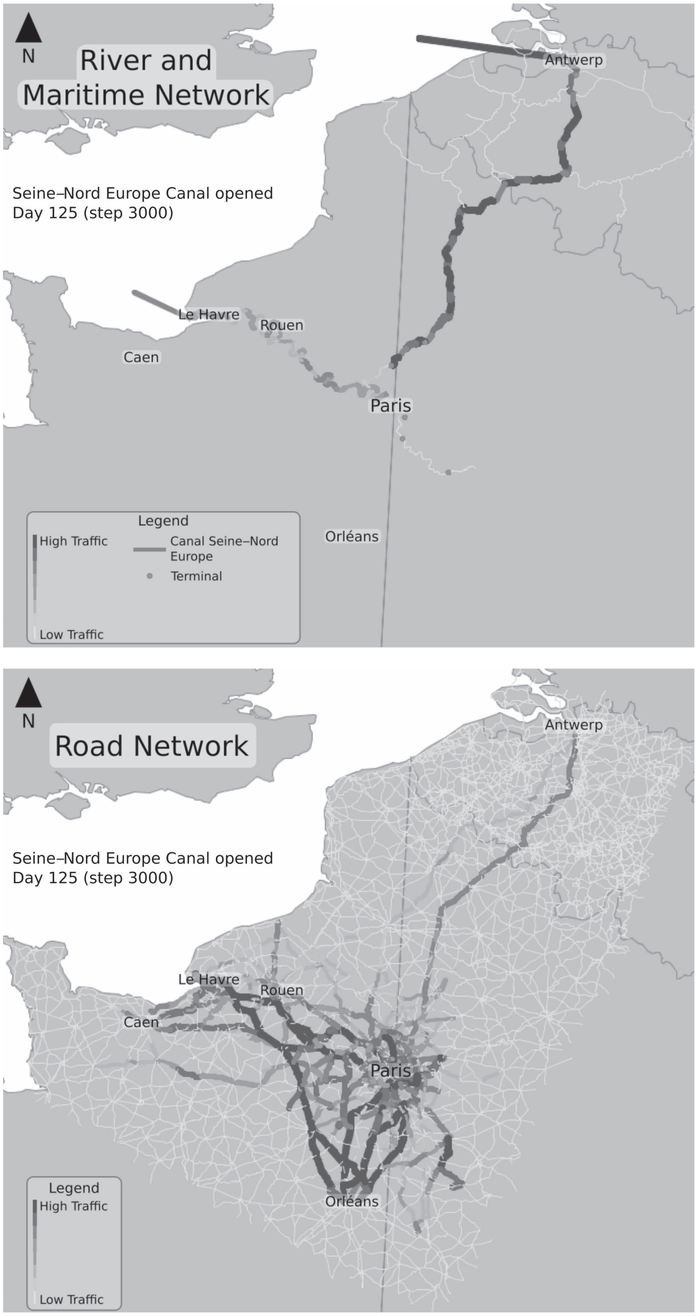

Figure 14.4 Screenshot: scenario 2 – flow of goods – the Seine–Nord Europe Canal is open. (a) River traffic (b) road traffic.

higher volume of road traffic between Antwerp and the Seine Axis when the SNEC is not activated. In other words, opening the SNEC diverts some traffic away from the roads. Indeed, when the SNEC is not activated, the transportation mode share (based on the average quantities of goods measured for road and waterway modes across the whole territory) is 38% for the river compared to 62% for the road.[2] When the SNEC is activated, the ratio changes to 50.1% for the river. Moreover, the SNEC is also beneficial from the perspective of average financial costs: these costs are 25% higher when the SNEC is not activated. Last but not least, opening the SNEC increases the competition between Le Havre and Antwerp: in the simulation without the SNEC, the number of LSPs that choose Le Havre and are selected by final consignees is 2.9 times higher than the number for Antwerp. With the SNEC activated, this value falls to 1.25.

Automotive sector: Impact of short sea shipping (SSS)

This part focuses on the automotive sector in the Seine Valley. Indeed, this industrial sector is well established in this territory, both in terms of suppliers and vehicle assembly plants, which entails large flows of goods throughout the territory, particularly of imported components. It is therefore a very appropriate choice of case study for evaluating the impacts of changing transportation modes on overall logistic performance.

The 12 main assembly plants considered in this study belong to several manufacturers. The produced vehicles are intended for the domestic market or for export. These production centres are limited in number but large in size and capacity. They need to directly import their raw materials, plus the parts supplied by subcontractors (OEMs). We assume that the manufacturer that owns the factory uses a logistics service provider. Examples include the Renault plant in Flins, the Alpine plant in Dieppe, and the PSA plant (now Stellantis) in Poissy. We include 12 medium-sized or large suppliers present in the territory. The parts are manufactured in their own factories and then sent to the assembly plants. These suppliers, likewise, request stocks from international suppliers. A number of these suppliers are actually internal to manufacturers. Examples of OEMs include Faurecia (Oise), Knorr-Bremse (Calvados), and Bosch (Mondeville-Caen). Lastly, 12 LSPs are included in the study, together with 10 regional and 10 national warehouses.

Four scenarios were explored with the principal aim of determining the impact of SSS on the automotive sector's import logistics chains. The impacts explored are (1) the total flow of goods throughout the transportation network, in terms of total pallets multiplied by kilometre; and (2) CO_2 emissions expressed in kilograms.

In the simulation, all goods arrive at the main maritime ports of Antwerp and Le Havre. SSS routes may then be used to reach one of the eight regional ports before sending the goods to national, regional, and final consignees. The simulation also takes into account the traffic from suppliers to plants.

Table 14.1 Flows (pallets × km), average for all scenarios (complete tables available on request).

Scenario	*km*	*Road*		*River*		*Short sea*	*Total*
		pallets × km	*km*	*pallets × km*	*km*	*pallets × km*	*pallets × km*
Scenario 1	2,111	202,745,956	377	191,726,695	693	175,007,674	569,480,326
Scenario 2	2,110	203,247,274	466	218,949,091	548	169,061,818	591,258,185
Scenario 3	2,170	207,899,138	466	208,805,129	446	134,575,840	551,280,108
Scenario 4	3,099	320,472,033	466	111,050,478	0	0	431,522,512

Table 14.2 Emissions (CO_2 kilograms), average for the scenarios.

	Road	*River*	*Short sea*	*Total*
Scenario 1	5,483,356	2,091,563	1,484,913	9,059,834
Scenario 2	5,496,914	2,388,535	1,434,463	9,319,914
Scenario 3	5,622,726	2,277,874	1,141,855	9,042,456
Scenario 4	8,667,311	1,211,459	0	9,878,771

The constants used for the calculation are: (a) road = 446.25 gCO_2 per km per TEU; (b) river = 180 gCO_2 per km per TEU; and short sea or maritime = 140 gCO_2 per km per TEU. Here, 1 TEU = 16.5 pallets (Clean Cargo, 2018; Ti & Upply, 2020).

In Scenario 1, since we assume that all ports are or may be able to handle containers, all ports (main and regional) are available as transshipment nodes. In Scenario 2, only two regional ports (Dieppe and Ouistreham) are available. In Scenario 3, only Le Havre's and Antwerp's maritime ports are active. SSS consists only of sending goods from Antwerp to Le Havre. Lastly, for Scenario 4, shipments from Antwerp's maritime port are all transported using trucks. Note that this scenario more or less reflects the current situation.

The simulation model prioritizes SSS, and also to some extent the river mode, when capacities allow for it. The economic criterion is not explicitly taken into account but can be computed from the pallet, multiplied by kilometre values for each mode. Furthermore, in our model, replenishment is carried out as soon as stocks fall below a given threshold. The distance from possible stocks is a key factor.

The scenarios were run as simulation experiments for a duration of two months of flows. Five experiments were run for each of the scenarios. The results are shown in Tables 14.1 and 14.2. The maps of the flows for Scenario 1 and Scenario 4 are shown in Figures 14.5 and 14.6, respectively.

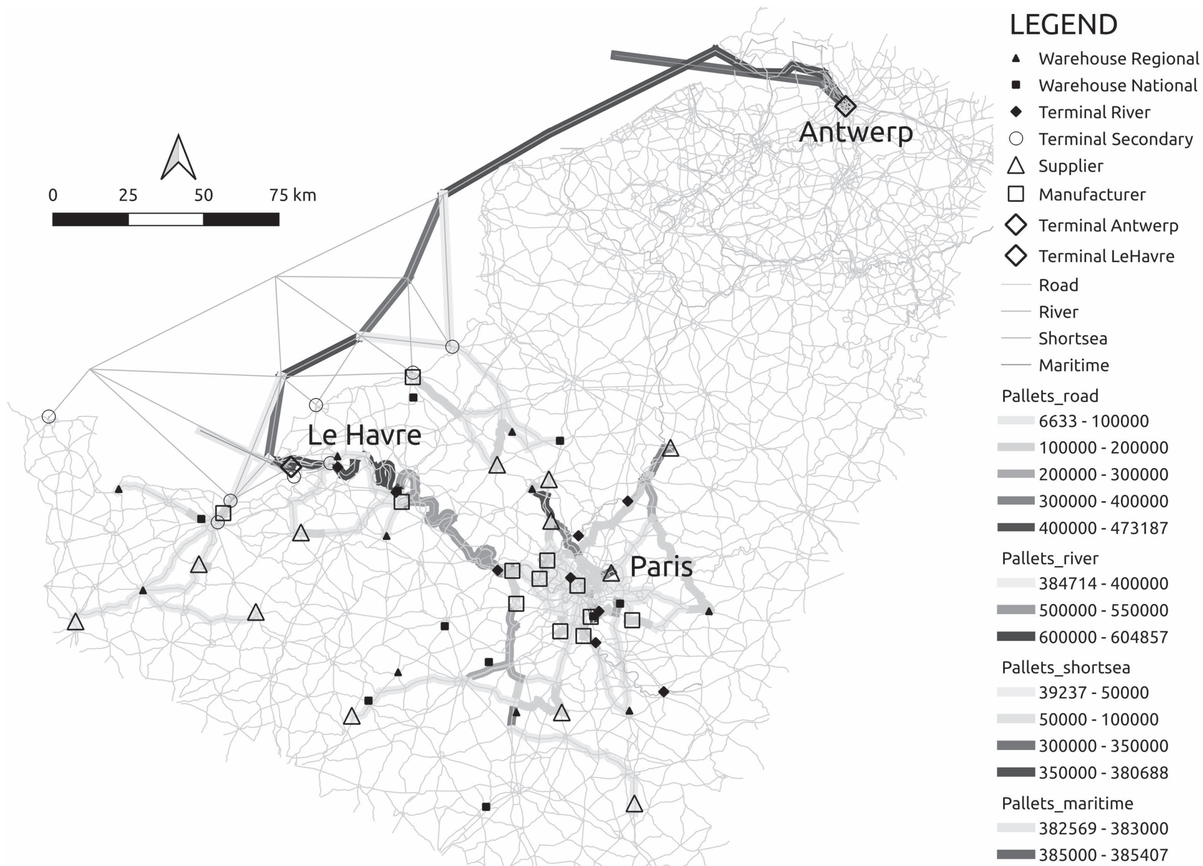

Figure 14.5 Scenario 1 (Run 1) flow of goods (in pallets). All ports are active. These values are taken at the 86,400th time step (equivalent to 60 days or 2 months of simulated time).

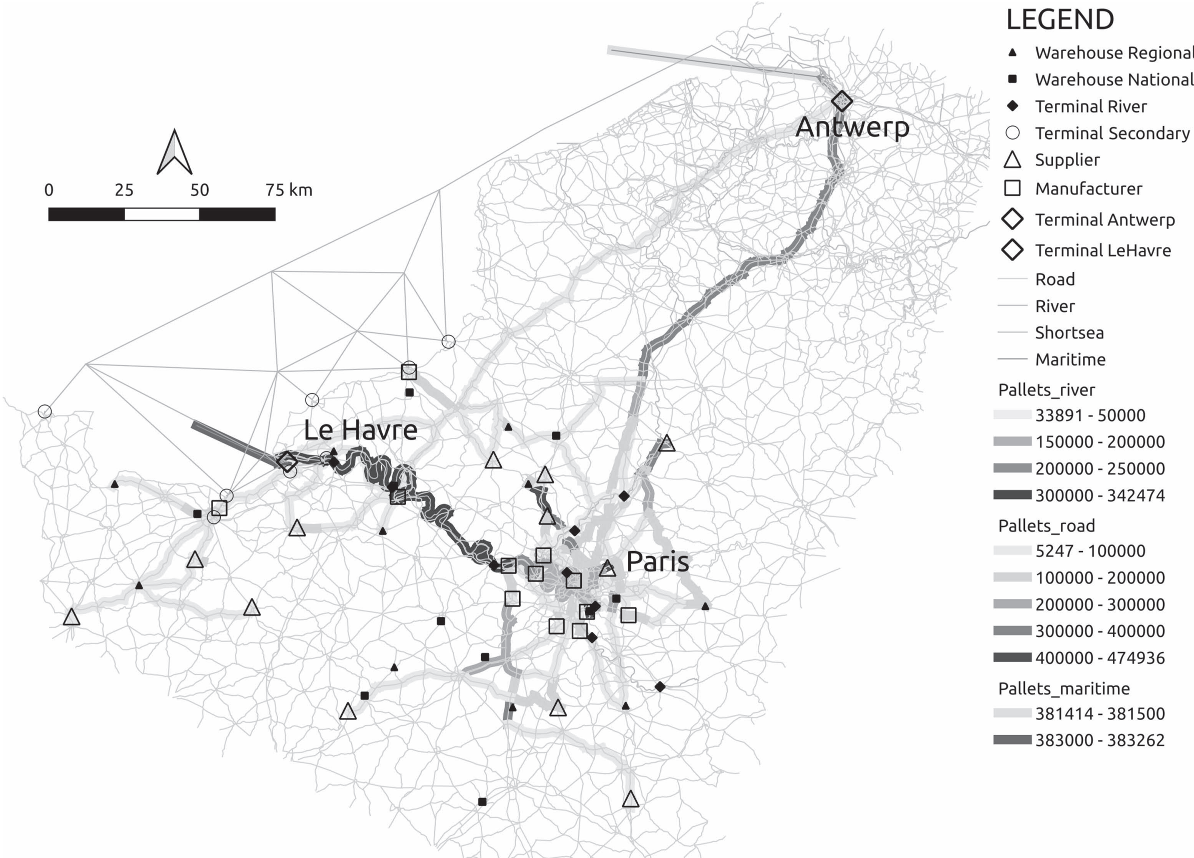

Figure 14.6 Scenario 4 (Run 1) flow of goods (in pallets). There is no short sea traffic (short sea ports are not active). The stocks from the port of Antwerp are transported to national warehouses via trucks. These values are taken at the 86,400th time step (equivalent to 60 days or two months of simulated time).

Discussion of results

Some observations can be obtained from the presented results.

(1) As expected, Scenario 4 has the highest emissions (the difference is around 10%).
Indeed, while the short sea mode is not used, the river mode is also much less used as all the goods from Antwerp use the road network. The pallets multiplied by kilometre criterion is better in Scenario 4, as distances via inland routes are obviously shorter, but the cost per kilometre is higher. The study also shows the considerable advantage of using SSS in terms of CO_2 emissions. As considered in the previous chapter, while the Seine–Nord Europe Canal may have an impact on this criterion, using SSS from Antwerp, coupled with a better use of the Seine and Oise rivers, may be more effective.

(2) When expressed in terms of pallets multiplied by kilometre, the figures for the three transportation modes are similar (except in Scenario 3). Although they do not reflect the present situation, they do illustrate that changing the relative parts of the mode is indeed feasible and realistic, at least for some sectors, if capacities are proposed. Note that if the river network was used as it is now between Le Havre and the Paris region, the CO_2 emissions would be significantly higher in all scenarios.

(3) The results of the first three scenarios are similar. Note that Scenario 2 seems the worst. In this case, the simulator did not use Dieppe as an auxiliary port because of the location of the national warehouses. Ouistreham, on the other hand, was used to serve the western-most region. In Scenario 1, only two regional ports were used: Le Tréport and Caen. This preliminary study should be completed to better understand the mechanisms that contribute to whether a given regional port is used. Here, the location of warehouses seems to be the key factor. Furthermore, SSS may only require a small number of ports to be opened.

Conclusion

(1) Using a complex system and multi-agent modelling approach was a good strategy. It offers high flexibility to (1) create a model of complex logistics systems in any territory; (2) integrate real geographic data; (3) explore different combinations of parameters; and (4) conduct simulation experiments with different scenarios.

(2) The two case studies emphasize that the geographic location of the nodes of the supply chains (terminals, warehouses) greatly influences the (1) emergence of supply chain clusters; (2) choice of transport nodes; (3) shipment arrival times; and (4) the resulting patterns of flows. The strategic positioning of these nodes (with respect to each other) should therefore be designed to encourage the emergence of a supply chain network with stable and optimal flows, as well as low emissions. The presented simulation tool represents a means of determining the best design for this network, but it should be complemented by optimization tools.

(3) Considering the impact of Seine–Nord Europe Canal, the results have to be handled with care, as they depend on input data that is sometimes difficult

to obtain (such as origin–destination flows). Still, the presented tool is sufficiently adequate to deliver "what if" studies at the request of decision-makers or the civil services.

(4) The same conclusions can be drawn for specific industrial sectors. In particular, the second study shows the possible significant impact of SSS. The proportion of SSS can be greatly increased, first by increasing the feeder traffic between Antwerp and Le Havre, and second by using a small number of regional ports. This has significant impact on CO_2 emissions.

To conclude, we believe the presented tool has great potential, but close collaboration with stakeholders will be required in order to produce an accurate model that offers meaningful results.

Notes

1 www.data.gouv.fr/fr/datasets/base-sirene-des-entreprises-et-de-leurs-etablissements-siren-siret/

2 The large proportion of river transport compared to reality can be explained by our current parameters that prioritize the most important flows.

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15 Simulation of modal shift and multimodality on the Seine Axis

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Introduction

A corridor is generally a bundle of infrastructure organized according to a linear model and involves many of the existing transport modes, such as rail, air, sea, and road transport, which complement one another and can be used in an intermodal manner. A corridor typically links distant territories through major routes with high volumes of traffic (Libourel, 2020). A good connection between modes is necessary in order to ease flows within corridors that feature a variety of transport modes and to improve the resilience of the transport system. In addition, users should be provided with detailed information on the transport services available and should be given help with selecting the optimal itinerary between a point of origin and a point of destination based on given requirements. A specific benefit of providing information on all available transport services is that it can prompt people to choose more environmentally friendly transport modes, such as rail or river transport. The work presented in this chapter is situated in this context and aims at providing improved intermodal connectivity within the Seine corridor. We describe the methodology used to develop two applications aimed at facilitating a modal shift.

In France, 87% of freight is transported by road, 10% by rail, and 2–3% on the waterways.[1] Despite recent progress, the trend towards a modal shift remains hesitant. This structure of the transport market is incompatible with the national and European objectives of carbon neutrality (Pfoser, 2022b) in the medium term. In addition, it poses a risk for logistics operators in the face of increasingly stringent, environmental legislation.

The starting point of our work is the consideration that the reluctance of shippers and freight carriers to commit to a modal shift is partly due to the difficulty of organizing and visualizing the effects of combining different modes of transport, including maritime, river, and rail transport in particular. Various studies have shown that the adoption of multimodal transport can cause freight carriers to feel they have lost control over the goods they are transporting, raising doubts about the reliability of multimodal transport.

Pfoser (2022a) highlights the barriers to multimodal freight transport. They are classified as demand-related barriers, shipment characteristics, infrastructure/

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supply barriers, organizational barriers, and legal/political barriers. To address these barriers, she suggests measures such as the internalization of external costs, providing efficient information, education and training, awareness raising, a harmonized legal framework, increased weight limits for multimodal pre- and post-haulage, increased capacity, and service improvements.

To address awareness raising, increased capacity, and service improvement, we have worked with Haropa port within the framework of the SFM rail shuttle service project (Service Ferroviaire de navettes Modulaires) on the simulation and optimization of container transportation between the port of Le Havre and the Moissy-Cramayel intermodal rail/road terminal in the Paris region before they are transported to the end customer (El Yaagoubi et al., 2021). This terminal is not currently operational. It first has to be sized before simulating container handling scenarios. Currently, our work is centred around the implementation of synchromodality on the Seine Axis in collaboration with the river carrier Sogestran within the Flusynchro project. Both simulation and optimization models (Archetti et al., 2021) are also used in this project. However, in this chapter, our primary focus will be on the simulation models developed in these two projects using the AnyLogic simulation tool.

Materials and methods

To build our simulations, we used AnyLogic, one of the most suitable agent-based modelling and simulation software. AnyLogic is a multi-method simulation tool that supports agent-based, discrete-event, and system dynamics simulation methodologies. Moreover, it considerably reduces the time and cost of developing models thanks to some useful libraries, including the Process Modeling Library, the Road Traffic Library, the Rail Library, and the Agent Library.

On the one hand, in the SFM project, the simulation involves the optimization of containers' storage and their unloading/loading scheduling (El Yaagoubi et al., 2022), as well as the optimization of truck routes to deliver and pick up containers from customers (Benantar et al., 2020). On the other hand, in the Flusynchro project, simulation and optimization models are used to find and simulate the optimal paths for the routing of a set of containers from an origin to a destination in terms of time, distance, and CO_2 emissions (Ferjani et al., 2022). Mathematical models have been developed to formulate these optimization problems (Ferjani et al., 2022; El Yaagoubi et al., 2022). Exact and approximate methods to solve these problems have been developed and tested efficiently.

SFM project

The project's main objective was to highlight the potential of mass transportation by railway on a local network and on a short axis (Le Havre–Paris) (less than 300 km). More specifically, our goal is the implementation of an efficient and cost-effective solution for the transfer of containers by rail shuttle between the port of Le Havre and the Moissy-Cramayel intermodal rail/road terminal in the Paris region (see Figure 15.1). The present study focuses on links 2 and 3.

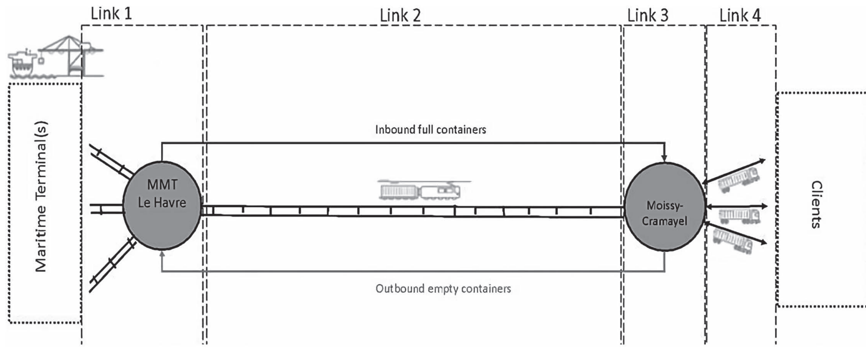

Figure 15.1 Logistics chain and its links.

Each shuttle is composed of eight coupons. A coupon is a set of seven wagons. Before its departure from the multimodal terminal of Le Havre, the shuttle is filled with full containers to be unloaded on their arrival at the intermodal terminal, which has both a rail and a road yard. The shuttle, which is composed of 56 containers (i.e. 8 coupons × 7 wagons), arrives at midnight and is supposed to leave before 5 a.m.

This compact terminal has been sized as follows (see Figures 15.2 and 15.3): the rail yard is composed of two tracks for the simultaneous unloading/loading of the containers of two coupons by crane. The rail yard has two container storage areas: first, a buffer to store containers to be delivered the same day, as well as to store empty containers brought by trucks which will be shipped to Le Havre with the shuttle, and second, a stationary storage area for the other full containers to be delivered later.

To implement the simulation model on the AnyLogic software, the following libraries were used:

- Rail Library: to simulate railway logistics operations. It allowed us to model, simulate, and visualize the train process.
- Process Modeling Library: to display processes of simulation models. These processes are specified in the form of flowcharts.
- Road Traffic Library: to plan transportation and design traffic and road traffic system management. This library has been used to simulate and display the truck process (truck movements).

There are three main types of agents in our model: containers, equipment, and transport means. Equipment and transport means are modelled as abstract agents. They are consequently non-instantiable, but their properties and behaviours are inheritable. In our system, the related instantiable agents are train, truck, and rail-crane. Other classes could be added if needed, such as ships, straddle carriers, and so on. A train agent is a composite agent: it combines a locomotive agent, dragging

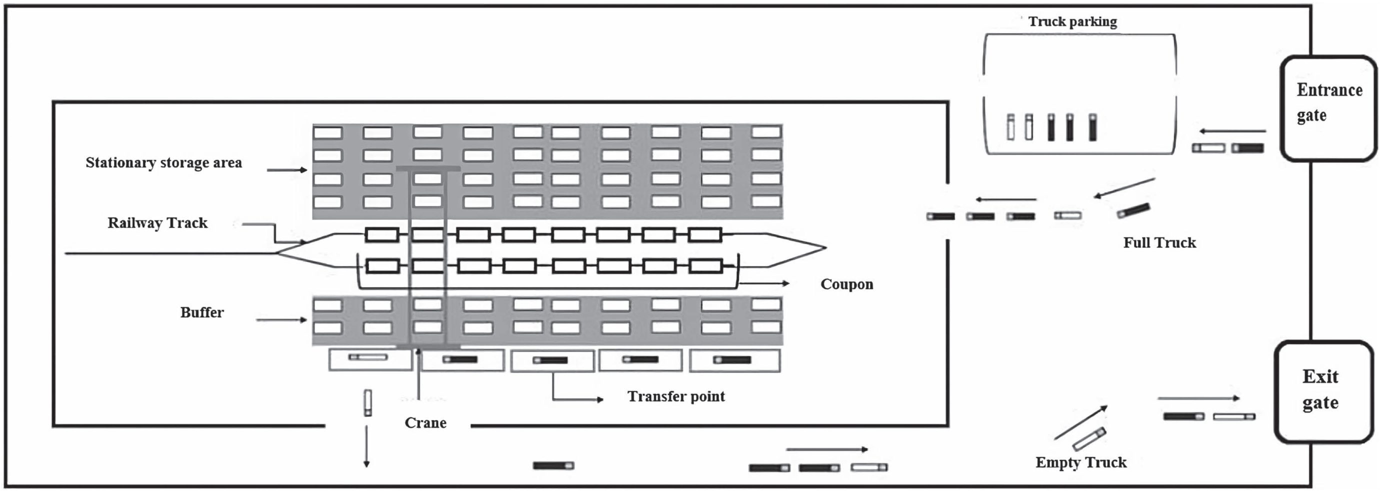

Figure 15.2 Truck and train operations in Moissy-Cramayel terminal.

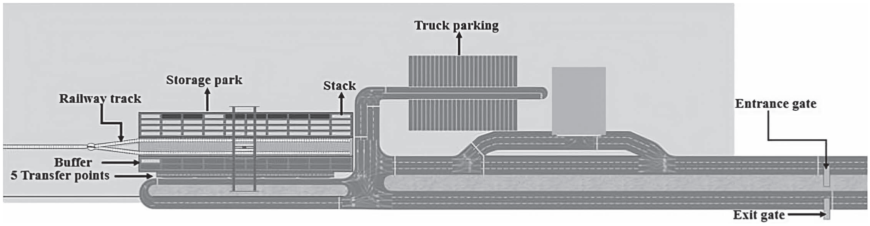

Figure 15.3 Yard layout of Moissy-Cramayel terminal in AnyLogic.

a set of railcar agents, with railcars, which are considered passive units because they are not self-driven. This organization of agents is an attempt to reflect the real nature and attitude of actors inside the terminal. The entity named "storage area" refers to the space where containers are stored waiting to be loaded onto transport means.

The main goal of the simulation is to optimize the overall handling time (unloading, loading, and storage of containers) of the shuttle from the time of its arrival to its latest departure time. Container handling is highly dependent on the container storage strategy, which can increase or decrease the number of unproductive loading and unloading movements (called shiftings). In this case study, we have simulated and tested two strategies. The first one is strictly based on simulation models, whereas the second is based on both simulation and optimization models (El Yaagoubi et al., 2022).

In the first strategy, once the coupons arrive at the rail yard, the unloading and storage of all full, inbound containers are based on their delivery time to the clients. Storage is organized according to the nearest empty stack to the crane. At the same time, the outbound, empty containers initially stored in the buffer are loaded onto the coupons. During the day, inbound containers are delivered to clients using trucks, and new, empty containers are returned from clients to the buffer of the rail/road terminal.

In the second strategy, we considered two scenarios which used an integer multi-objective mathematical model specific to each scenario and displayed two objective functions: one, the minimization of the number of shiftings during container delivery to the clients and, two, the maximization of the number of empty stacks in the storage area (El Yaagoubi et al., 2022). The basics of multi-objective (combinatorial) optimization are clearly explained in Emmerich and Deutz (2018) and Ehrgott (2005). Indeed, in our study, the containers scheduled to be delivered first are positioned on the top levels of the stacks to avoid unnecessary shiftings during the day. Moreover, having additional empty space in the buffer at the end of the handling operations is valued in our case study: it is necessary to have enough space to unload the outbound empty containers arriving by trucks in the buffer as the unloading must be done in an initially empty stack. Accordingly, maximizing the number of empty stacks in the buffer at night helps the handling of containers when trucks arrive during the day.

In the first scenario (see Figure 15.4), only the buffer is used, while in the second scenario (see Figure 15.5), both storage spaces are used (the buffer and the stationary storage area). In both scenarios, empty containers are loaded from the buffer onto coupons at the same time as full containers are unloaded from coupons. However, in the first scenario, full containers are unloaded from coupons into the buffer, while in the second, full containers are unloaded from coupons into the buffer or the stationary storage area based on their urgency (i.e. their delivery day). In other words, the containers to be delivered the same day must be stacked in the buffer, whereas those that will be delivered later must be stacked in the stationary storage area.

Furthermore, in the first scenario, it is assumed that the buffer is full of empty containers before the arrival of the shuttle, while the stationary storage area is empty.

Meanwhile, in the second scenario, it is assumed that the buffer is full of empty containers and the stationary storage area contains some non-urgent full containers delivered days before.

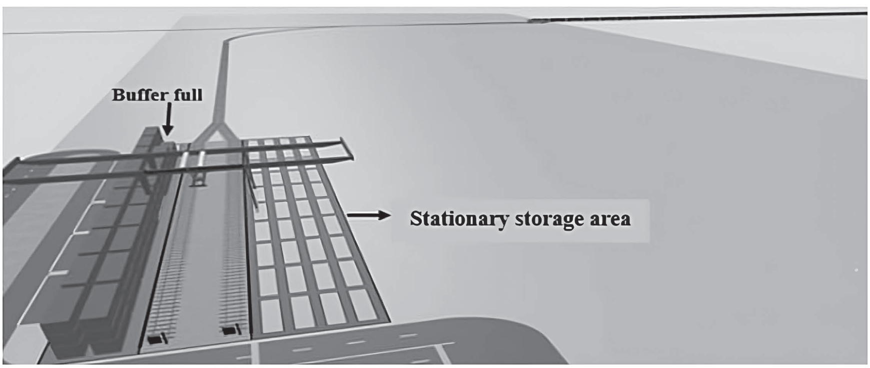

Figure 15.4 Screenshot of simulation of the first scenario in 3D.

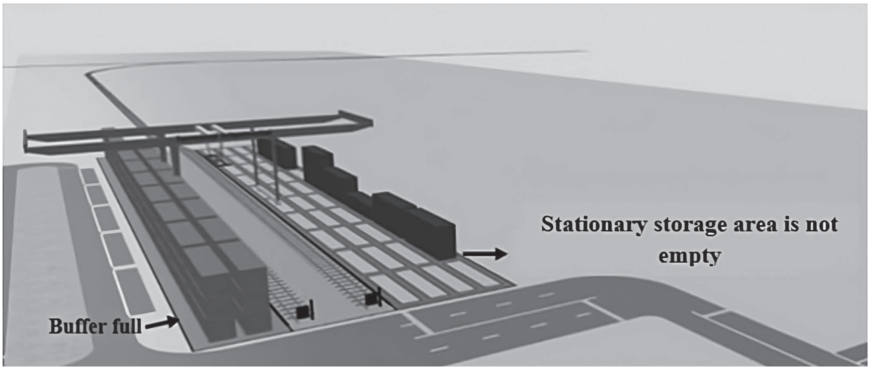

Figure 15.5 Screenshot of simulation of the second scenario in 3D.

Table 15.1 Comparison of the two scenarios.

	Departure of the shuttle (a.m.)		*Handling time without optimization (in hours)*	*Handling time while integrating optimization results (in hours)*	*Time saved (in hours)*
	Without optimization	*With optimization*			
Scenario 1	04:20	03:30	4 hr	3 hr	1 hr
Scenario 2	04:12	03:15	3 hr 47 min	2 hr 35 min	1 hr 12 min

Table 15.2 Key performance indicators results.

KPI	*Strategy 1 (in seconds)*	*Strategy 2: with optimization (in seconds)*
Crane handling time	74	62
Service time	74,617.23	56,347.89
Active time	14,422.23	12,796.89
Idle time	60,195	43,551
Truck service time	50.34	43.35

To simulate the two scenarios, we assume that the shuttle is composed of eight coupons of seven wagons (7 × 8 containers) and that it arrives at the terminal at midnight. The “Without optimization” heading means that the crane drops a container in the nearest available stack, while the “With optimization” heading indicates that optimization models have been used to load and unload containers. Table 15.1 shows that optimization significantly reduces the time spent by the shuttle in the intermodal terminal. It is thus evident that Scenario 2 is more efficient than Scenario 1 (see Table 15.2).

We then compared the crane handling time, the service time, the idle time, and the truck service time of the two strategies. The second strategy, which uses optimization (El Yaagoubi et al., 2022), decreases these times respectively by 16.21%, 24.48%, 27.65%, and 13.88% when compared to the first strategy.

Flusynchro project

The Flusynchro project is intended to optimize multimodal freight transport on the Seine Axis (Ferjani et al., 2022). The aim is to compute the optimal paths from an origin to a destination in terms of time, distance, and CO_2 emissions, while minimizing container offloading during transit, mainly at the following waterway terminals (see Figure 15.6): Le Havre, Rouen, Limay, Gennevilliers, Longueil-Sainte-Marie, Bonneuil-sur-Marne, and La Bourdonnais (Paris).

In the first stage, the optimization and simulation models are developed without taking into account uncertainties (Ferjani et al., 2021) related to transport time, waiting time, and service time (next stage). The shortest paths in terms of distance, time, and CO_2 emissions are calculated by optimization and displayed by simulation. This first stage of our models’ development will be the focus of this section.

Figure 15.6 Geographical locations of the waterway terminals.

The UML model (see Figure 15.7) illustrates our synchromodal system. It includes the transport of containers between the multimodal terminals and/or the customers (warehouses) present on the Seine Axis in France.

This model is mainly composed of seven classes. Let us start with the class "Terminal," which refers to the multimodal terminals considered in our case. A terminal is considered using its name and location on the map.

We also consider the class "Customer" to refer to the different customers located near the terminals, which is to say within a distance less than or equal to 50 km.

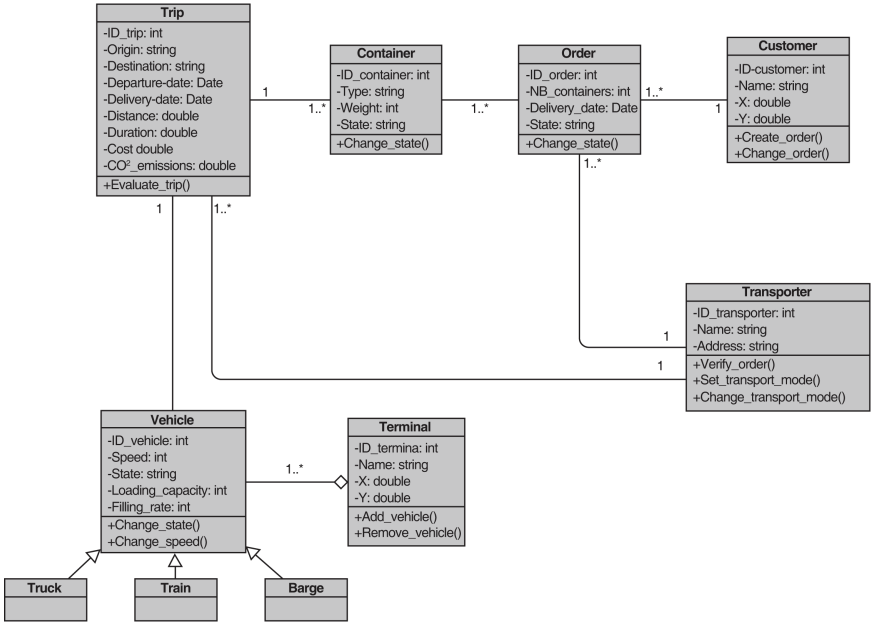

Figure 15.7 Relationships in UML class diagram.

A customer can create and make one or more orders, and the transportation modes of these orders are determined by a transporter. We represent the transporter with a class characterized by the name of the company and its address. Based on the orders details, customers' requests, and available information on the transport flow, the transporter verifies the order and then selects the most suitable transportation mode, which can also be modified according to possible changes in the transportation system.

Each order is characterized by the delivery deadline, its state indicating whether the order has been satisfied or not, and finally the number of containers required by the customer. An order can be composed of one or more containers. Therefore, a composition relationship links the classes "Order" and "Container." A container is then characterized by the attribute "Type" which indicates whether it is a 20 or 40 ft container. Containers can be transported from/to multimodal terminals and customers by vehicles which are represented by the class "Vehicle." Our model distinguishes between three derivatives of vehicles: trucks, trains, and barges. The vehicle's state may change during the trip organized by the transporter. The class "Trip" is mainly characterized by the origin and destination addresses, which can be terminals or customers. A trip is also characterized by the distance, CO_2 emissions, and time elapsed between the origin and destination addresses. These attributes are essential for evaluating a trip and, consequently, the performance of the entire transport system.

The three transportation networks – road, railway, and waterway – are then considered. These networks have been modelled as a multilevel graph (see Figure 15.8) so that a multicriteria optimization algorithm – a new variant of Dijkstra's algorithm adapted to the multimodal transportation network – could be applied (De las Casas et al., 2021; Sedeño-Noda & Colebrook, 2019; Clímaco & Pascoal, 2012). The algorithm uses multi-objective optimization to identify the optimal route, namely the one that offers the best compromise between the three criteria (distance, time, CO_2 emissions) for transporting a set of containers from an origin to a destination. Furthermore, we apply the weighted-sum approach by assigning weights to the three studied criteria. The user can also weight these criteria. The optimization algorithm is then launched to determine the optimal path, taking into account the assigned weights.

Once the shortest paths in terms of time, distance, and CO_2 emissions have been calculated by the optimization model (an illustrative example is given in Figure 15.8), the routing of the containers through these paths is simulated (see Figure 15.9) (Ferjani et al., 2022). The simulation is carried out to evaluate these

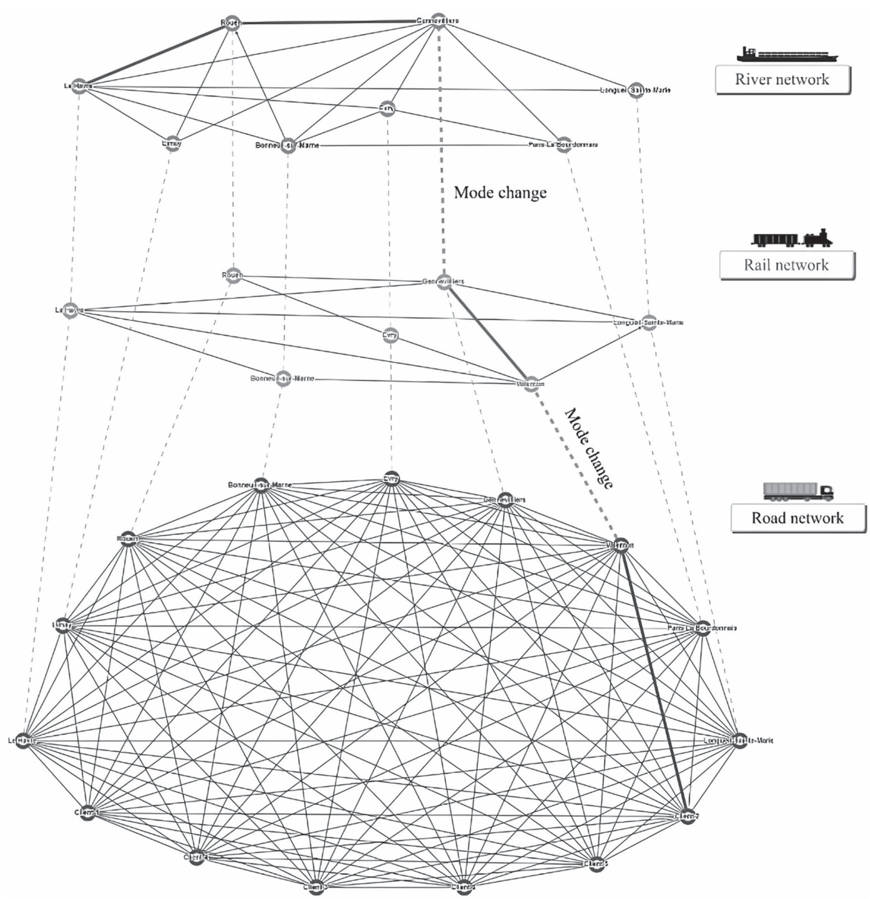

Figure 15.8 Multimodal transport network.

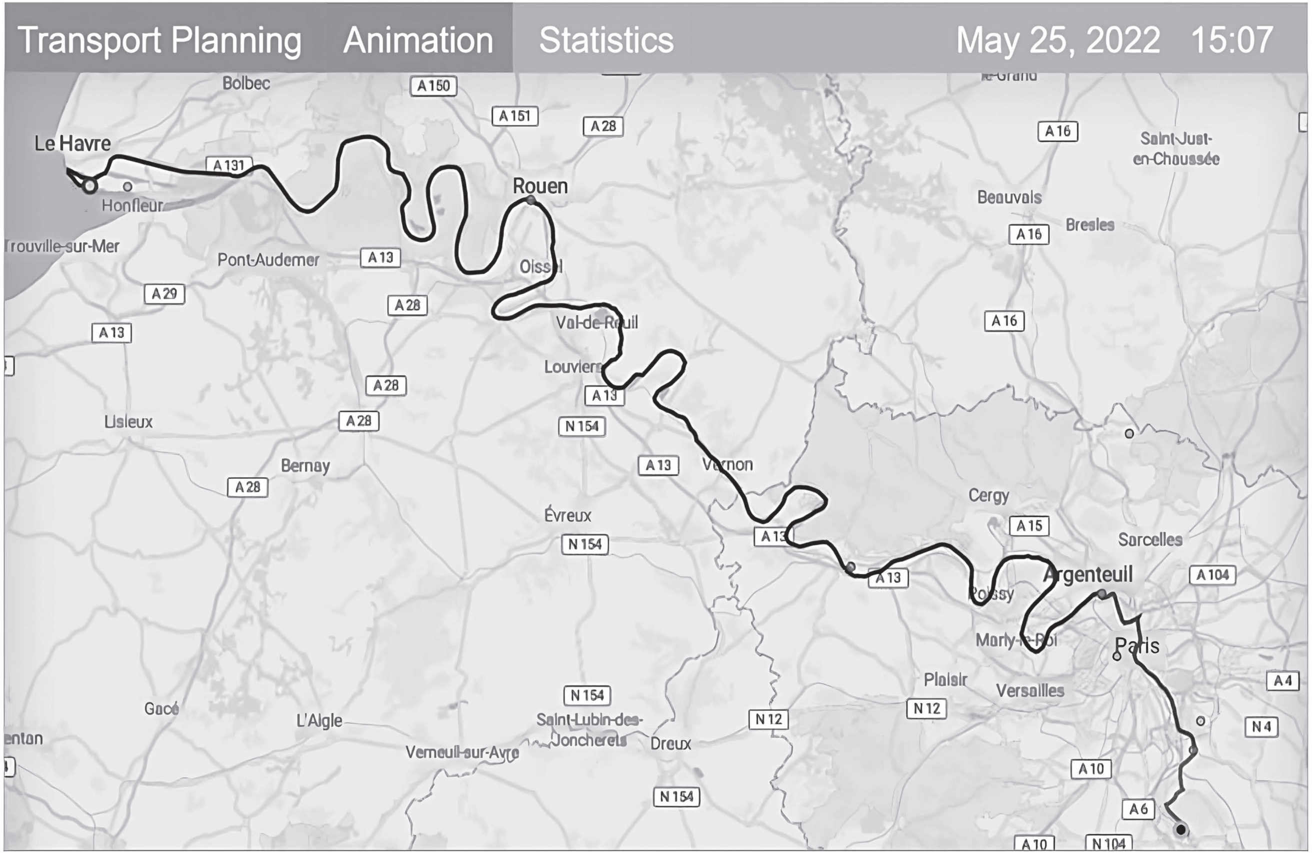

Figure 15.9 Screenshot of a simulation.

paths, as well as to consider the uncertainties related to the transport time (especially for the road) and service time spent inside the terminals while changing modes.

Conclusion

In this chapter, we have highlighted how transport simulation and optimization can improve our understanding of multimodality options and connections within a corridor. Meanwhile, the simulation models we have developed are general and can fit other geographical environments. As part of the Flusynchro project, future studies will consider uncertainties related to transport and service times at multimodal terminals in particular (Ferjani et al., 2021). Optimization models will eventually be able to take real-time unexpected events into account (i.e. infrastructure availability, congestion) when selecting the optimal path.

In addition to carbon emissions, it would be interesting to consider the impact of externalities, such as pollution, congestion, and noise, by drawing on a study led by CE Delft examining the external costs of transport (European Commission et al., 2020). The congestion cost, as indicated by the study, has a high impact on road transport. To expand on this, the study 1) suggests that for each type of externality and for each mode, the proposed marginal costs × freight tonne kilometres (FTK) for rail, inland waterway, and road should be used; 2) offers a list of vehicles for each mode of transport; and 3) distinguishes between urban and rural areas.

The developed applications are now functional, and it is quite possible that they will be taken over by a professional for commercial use. Nevertheless, the real-time aspect has not been addressed (we currently have to generate the events for the simulation) because of the difficulty of interfacing the platform with information systems, such as the waterway information system of the French navigation authority, VNF, or other rail and road traffic systems.

Acknowledgement

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Note

1 https://splott.univ-gustave-eiffel.fr/fileadmin/redaction/SPLOTT/documents/divers/_Maquette__Tableau_de_bord_de_la_logistique_-_2022.pdf

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Fourth section

Towards sustainable corridors through environmental and energetic transitions

16 Developing sustainable port areas

Economies of scale and scope in the context of a corridor-sized port

Marie-Laure Baron

Introduction

Corridors play a major role in delivering energy to wherever it is needed. Petroleum is moved through the main ports before it is unloaded and routed towards refineries, predominantly located by the sea, to be transformed into final products. Imports, in turn, historically gave rise to the expansion of petrochemical industries in the vicinity of ports and along routes to the main consumption areas. Ports and corridors are therefore key infrastructures for European countries' energy supply. The pivotal position of ports in the energy supply and energy-related industry, coupled with the ongoing energy transition, means ports and corridors must radically evolve to support national and European commitments to reducing oil-dependency and carbon emissions. Besides being energy hubs, ports are also key logistics nodes where many maritime and other transport flows converge. Road transport constitutes the highest proportion of overall transport emissions, and the European transportation sector is the second-highest carbon emission producer in Europe, with its emission levels making up 23.2% of European emissions. Moreover, if no additional measures are taken, transport emissions are not expected to fall until 2030. Port areas therefore face high environmental stakes.

If "interaction between the port and inland actors" is required to reduce carbon emissions (Bergqvist & Monios, 2019), one might question how it helps when the port authority broadens its reach to embrace part of the hinterland. The port's responsibility with regard to the production of carbon emissions may not grow as fast as opportunities to green the hinterland and to promote the transformation of current business conditions for the better. In this chapter, we propose to investigate how increased size, scale, and scope can enable the port authority to better contribute to decarbonization and to build a green port cluster.

The Seine Valley is home to the recently created port of Haropa, a unique structure formed by the merger of three formerly independent port authorities that are nodes along the same corridor (Le Havre and Rouen – both maritime ports – and Paris, an inland river port). Haropa has therefore acquired the ability to act at the scale of the entire corridor. Although the port area itself is only a small portion of the geographical space covered by the corridor, the whole area straddling Normandy and the Paris region is of direct economic significance to the port's business

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development, whether in terms of flows, rents, or connections. As a public port authority, Haropa needs to support customer and user conversion within the large port territory it governs in order to achieve the objectives of net zero greenhouse gas emissions and of no net land take by 2050. Beyond the port area, this challenging conversion can also rely on the wider arena along the Seine River which, depending on how the new assemblage grows, can provide the port with throughput, industrial space, or other resources.

We focus on the land dimension of the transformation, exploring the framework and the levers the port authority can use to convert its own business as well as to support the corridor shift. In order to give a measure of ongoing and future achievements, we first describe the current features of ports and port industries before outlining the significance of the challenge faced. We then analyse how the emergence of economies of scale and scope, brought about by the Haropa port merger, offers certain advantages. The chapter emphasises how size, scale, and scope give ports greater legitimacy with regard to coordinating multilevel action to revamp the business ecosystem.

Corridor sustainability and port authority action

In transport geography, a transport corridor traditionally designates roads and major transport infrastructure linking metropoles (Gottmann, 1961). The corridor also services a port or gives access to resources in interlocked areas and is typically dense in transport flows (Comtois, 2012). Haropa links three metropoles, services two maritime ports (Le Havre and Rouen), and is dense in transport flows. Three port areas that were previous separately managed are now combined under the management of a single authority in order to act at the scale of the corridor, making it a unique setting.

The energy and ecological transition will have a significant impact on industry, ports, and transport corridors. Due to changing consumption patterns downstream and collective environmental commitments, the industry and logistics players must evolve towards more sustainable productive modes. While traditional petrochemical products are becoming less acceptable (Molle & Wever, 1984), the industry has seen the development of new biorefining techniques which use alternative raw materials, such as agricultural products or used vegetable oils, and for which the proximity of a port is less important. Transition fuels also produce less throughput for the port than the amount fossil fuels produced previously. Moving away from fossil fuels also means making alternative energy sources available, scalable, safe, and economically viable. Wind, nuclear, solar, and biogas power, as well as stored hydrogen from water electrolysis, may all be generated within port areas. As the generation of offshore wind power is expanding along with the production of decarbonated hydrogen and carbon capture, ports may become energy hubs that receive, store, and provide clean energy flows. The energy transition thus provides ports and corridors with an array of opportunities to support the conversion of existing businesses and improve their carbon footprint. Most experts believe that multiple energy sources will be used in the coming decades to replace fossil fuels. They will be combined and converted into electricity until a dominant energy source emerges.

Another concern is the transport that serves or runs along the corridor. Multimodal transport that uses the rail or river should be promoted to contribute to national and European environmental objectives. In order to lower greenhouse gas emissions, all transport modes will also have to change the propulsion technology they use and consequently their energy supplier.

Because they manage the port's landside and seaside operations, port authorities can play an important role in spurring change (Poulsen et al., 2018). As landlords (providing land and basic infrastructure), regulators (setting tariffs and standards), operators, and community managers, they must support the modal shift within the port area they manage. The green port concept is a step towards green growth in ports. Green ports have attracted academic attention (Chen et al., 2019; Bergqvist & Monios, 2019; Christodoulou & Cullinane, 2019; Cullinane & Cullinane, 2019; Tseng & Pilcher, 2019). Many contributions focus on a particular dimension of green ports, such as energy and shipping activities (Christodoulou & Cullinane, 2019; Chen et al., 2019) or circular activities (De Langen et al., 2020; Cerceau, 2013), but none are dedicated to investigating the challenges involving port authority action and corridor sustainability. At the port level, acting as a green port is often a matter of applying regulations in the short term (Bergqvist & Monios, 2019), which suggests that ports do not consider their environmental engagement as a completely strategic opportunity (Lavissière et al., 2019). In the case of Haropa, we propose that, beyond commercial, shipping, safety, security, or regulatory concerns, the remodelled entity's economies of scale and scope improve the port's ability to support change across a wide range of fields and actors. In this way, the port is better able to shape the future hinterland.

Supporting the conversion of the port area is not straightforward. First, besides having improved industry profiles in their areas, ports would benefit from the emergence of renewed interdependencies within industries to promote the anchoring of firms. A thriving and balanced but declining industrial ecosystem (De Langen et al., 2020) would become a renewed prosperous and harmonious ecosystem where complementarity between businesses is the rule. This is gradually made possible as various sites convert to new production modes, illustrated by the transformation of the port of Jerome in the Seine corridor between Le Havre and Paris, a river port engaged in refining and petrochemical activities. Loop Industries, Suez, Eastman, and Futerro are setting up bio-refineries and "bio-renewable" plastics and recycling factories as circular activities. Among the arguments in favour of the plans, project promoters mention easy access to decarbonated and renewable sources of electric power; the opportunity to share the steam generated through the production process with other industries; waterway and port proximity; and access to agricultural waste and employees trained in the chemical field. All of these elements point not only to the importance of retaining a variety of resources to attract investors, including energy and ports, but also to a legacy inherited from former ecosystem interdependencies that may not be as effective as before. A second constraint emerges as a result of the EU's commitment to achieving "no net land take" by 2050, which accelerates the timeframe within which changes must take place. Land take is defined in France as the "long lasting alteration of all or part of the ecological functions of land . . . by occupation or usage" (WIPO, 2021, author's translation). The objective of "no net land take" requires that any new operation involving soil sealing must be compensated for by recovering the equivalent amount of land. By 2030, the rate of land take must have been reduced by 50%. This suggests that the conversion of port areas cannot involve much land use. As urban sprawl continues to increase and the demand for new land keeps rising, new land use for transport infrastructure, energy, industry, or logistics, will also compete within the corridor with land use for housing, shopping, and leisure amenities. Land requirements could partially define corridor development characteristics. While wind power does not require much land, the land requirement of solar energy is one hectare per installed megawatt. Unless there is some degree of innovation in multifunctional land use (Vreeker et al., 2004), ports may come up against a lack of space for converting former industrial zones. In any case, the situation calls for connecting with local authorities and citizens, which both demand an improved environmental status along with good economic conditions and jobs. What then are the levers available to a corridor-sized port authority in the process of building a sustainable and well-developed economic area?

The large-scale port authority and corridor transformation

Most Western European ports are concerned with the transformation of their hinterland. The transformation affects their earnings from land leases or port throughput and threatens port attractiveness. For these reasons, ports need to drive change as much as they can by providing the infrastructure that meets future needs and by connecting with a variety of players to turn the external pressure into an opportunity. The challenge here is precisely to avoid the upheaval of discontinuous change, to retain former business where possible, and to benefit from new business opportunities in a new business model. The setting up of Haropa presents an opportunity to investigate the levers that might be offered by the size and perimeter of the port. In view of the foundations that were previously outlined, we have observed several steps that can be taken by the port authority. These involve reducing greenhouse gas emissions and land use by: 1) developing carbon capture services; 2) developing multimodal transportation (Pfoser, 2022) and improving the use of existing infrastructure; 3) supporting the conversion of existing industrial sites into more environmentally friendly businesses; 4) making the most of circular economy opportunities (De Langen et al., 2020); and 5) attracting new firms that have the same environmental ambition, with land compensation where necessary.

To make size a differentiating port characteristic, the conglomeration of ports must establish new valuable synergies and better/greater interaction within the corridor (Bergqvist & Monios, 2019). Benefiting from synergies and building on improved cooperation both necessitate a renewal of managerial practices.

According to Chandler (1994), mergers are particularly beneficial when they exploit economies of scale or scope. Bigness can lead to economies of scale and scope (Walter & Barney, 1990). Economies of scale derive from increased returns when the size of production, marketing, or procurement operations increases, and they are linked to specialization. There are also "economies of scope where it is less costly to combine two or more product lines in one firm rather than to produce them separately" (Panzar & Willig, 1981). These derive from the spreading of fixed costs over an expanded product mix and cost complementarities among product categories in production. Excess infrastructure capacity may be reduced by producing new services jointly rather than separately, with the same head office fixed inputs. However, economies of scale and scope depend on the ability of firms to make an investment in management and organization (Chandler, 1994). Hierarchy (coordination and control of complex production and distribution activities) then allows the firm to coordinate the allocation of resources efficiently and capture economies of scale and scope.

Walter and Barney (1990) list the many goals that may be pursued by managers in a merger and synthetize them into four larger categories. Notably, they find that mergers enable managers to: 1) obtain and exploit economies of scale and scope to gain efficiency, 2) deal with critical and ongoing interdependencies with firms in their environment, 3) expand their current product lines and markets, and 4) enter new businesses. Table 16.1 summarizes these different categories and provides some examples of the economies of scale and scope produced by a merger as applied to ports.

Regarding horizontal mergers, as is the case with Haropa, the authors found that there was no single dominant goal, and the companies accomplished several

Table 16.1 Benefits from merging port authorities.

Obtain and exploit economies of scale and scope	Promote visibility with investors and users. Use the existing infrastructure in a better way. Utilize skills and knowledge of other ports.
Deal with critical interdependencies (Pfeffer & Salancik, 1978; Williamson, 1975)	Accelerate growth and reduce risks and costs by benefiting from others' strengths. Utilize synergetic qualities of the merging ports (e.g. a joint sales force [Trautwein, 1990], knowledge transfers [Porter, 1985]). Gain complementary financial features such as those that balance earnings' cyclicality or allocate capital more efficiently. Improve efficiencies and reduce risk in the supply of specific goods and services.
Expand their current product lines and markets	Attain improved competitiveness inherent in holding a sizeable market share or important market position. Expand capacities at a lower cost than assembling new facilities. Penetrate new markets by utilizing marketing capacities.
Enter new businesses	Gain valuable assets.

Source: Adapted from Walter and Barney (1990).

goals simultaneously. The new authority was able to improve their efficiency by exploiting economies of scale and scope, deal with critical interdependencies along the corridor, and expand current product lines and markets. However, although it was often claimed that managerial and operational synergies would be established, these did not always come to fruition (Trautwein, 1990).

Haropa was created only recently in June 2021. As the new authority was being established, the first suggested change was that the three port communities would be represented within the new development council through a single body assimilating all three communities. The new port authority would then interact with a single "corridor" body representing the whole of the port community. However, the idea was poorly received by port community members as they argued there was a functional need for direct interaction between each individual port and its local community. The plan eventually evolved to satisfy stakeholders, and port communities now sit within the three development councils that were set up at the level of each port. This scenario indicates a strong feeling of belonging to a specific port area among port users, rather than a ready acceptance of the corridor-sized port. If the relevant territory is the one that is delimited by the stakeholders (Pecqueur, 2006), Haropa, and the corridor, do not seem to spontaneously exist as a reference area in the minds of community stakeholders, which raises questions about the potential and the opportunity of creating a new geographical space. There are 100 km separating each port, and it is evident that the historic competition between them – especially between the ports of Le Havre and Rouen – still exists.

Walter and Barney's classification was designed to explain how mergers lead to a competitive advantage. In today's context, building an environmentally friendly corridor gives ports a competitive edge in terms of flow, firm, or worker attractiveness. The framework proposed by the authors can therefore serve as a foundation for understanding how the port authority could improve the environmental footprint of port-related businesses.

Greater efficiency through the exploitation of economies of scale and scope

Consolidated management of the entirety of the corridor port area should improve resource allocation and coordination. First, the end of inter-port competition reduces the probability of low-productivity investment duplications, as any investment within the corridor can be carefully located and then promoted along the corridor to encourage usage as well as capacity management. Second, consolidated management may also make it easier to dedicate differentiated geographical areas to given activities. For example in the region between Le Havre and Rouen, important wildlife sanctuaries and nature reserves restrict access to land. Indeed, thanks to the merger, new land and land use opportunities are likely to arise. Third, each port within Haropa also holds specific knowledge and access to customers. Le Havre is focused on worldwide maritime transport, while Rouen is specialized in handling agricultural products, and the port in Paris is an inland city port focused on real estate management. By combining and better using the resources, skills, and knowledge of the three ports, the unified entity can benefit from economies of scale. Improving the visibility of the corridor-sized port, in addition to defining a single strategy and ensuring that resources are better allocated, promises to bring benefits in terms of customers, subsidies, and investor attractiveness to all three ports. Peng et al. (2005) argue that the scope of a firm is driven by a combination of product and institutional relatedness. Institutional relatedness is "the degree of informal embeddedness or interconnectedness with dominant institutions." It confers resources and increases the legitimacy of an organization (p. 623). Institutional relatedness helps firms capitalize on economies of scope based on three non-market forms of capital: social capital, political capital, and reputational capital. In the context of the many challenges of the energy and environmental transition, institutional relatedness may allow the more legitimate merged entity to be more efficient in obtaining public investment in the rail, river, or energy infrastructure needed to achieve the objective of reducing the environmental impact of the corridor. Shortly before and after the merger, Haropa entered into agreements with the French national and regional rail services (SNCF) and with the national waterway manager (VNF). It was easier and more legitimate for these partners to come to an agreement with a single port authority, which could consider the whole of the corridor area. The reach of Haropa also made the port authority more legitimate when discussing shared corridor challenges with cities such as Le Havre, Rouen, or Paris, where decisions to support port development were being taken. In December 2022, 12 cities along the River Seine (including Le Havre, Rouen, and Paris) entered into an agreement in which they committed to supporting the development of transport, logistics, and other areas such as tourism and culture. Two to four more cities are preparing to join in. The various hydrogen plans that were launched in France in 2018 to foster the development of renewable energy, or the setting up of solar plants, required debates on where production or distribution services should be located and how transport should be dealt with. These discussions engaged all players along the corridor and encouraged the rise of a corridor mindset. Obviously, the unified port authority benefits from this much-improved institutional relatedness as it reduces the cost of coordinating on a number of subjects that impact the corridor's development. The enhanced influence of the port authority should translate into improved knowledge about the port business within the corridor, port promotion, and port efficiency (better knowledge and use of existing infrastructure, improved environmentally friendly connectedness, attraction of new businesses, new services).

Dealing with critical interdependencies at the corridor level

A key characteristic of corridors is that they require a high degree of coordination. Today's logistics corridors need to develop a reliable, timely, cost-effective, and environmentally friendly transport and logistics network. These requirements are expected not only for the delivery of goods but also for the recycling process. The interdependencies of decisions and operations reveal the critical need for coordination along the corridor. Interdependencies also exist because an investment in renewable energy in the port of Le Havre area may support an industry close to Rouen or Paris. Or Paris may need to call on Rouen's and Le Havre's port areas and port operators to deal with urban waste. Coordination is necessary to develop a climate-resilient multimodal transport system. While most freight trains are now electric, barges are also evolving with the introduction of new types of ship propulsion (liquefied natural gas, hydrogen powered/electric), which means that port authorities, the waterway manager, and energy providers must coordinate their action to standardize equipment and provide energy along the river and docks. The change in energy provision will lead to the standardization of quay equipment (for onshore power supply) all along the River Seine, possibly with several energy solutions. Improved fluidity achieved through better coordination will also allow a more unified way of interacting with users along the corridor for bunkering, waterway, and rail terminal operations or customs. Finally, Bergqvist and Monios (2019) note that there are a very limited number of measures of port activities' impact on the hinterland. The single-window cargo community system that has been in use for several years now along the River Seine, or the Seine River Information System (provided by the waterway operator), illustrates the benefits of unification. Not only does it save users from connecting to several systems when using the corridor, but it also provides an overall picture of transit times, flows, and transporting conditions across the corridor. With all players connected to the cargo community system, and all freight flows traced through it, the corridor-sized port authority can benefit from this way of measuring cargo-related emissions and other indicators that can help drive change.

Increased variety within the industry network also multiplies opportunities for interaction – such as the interaction needed in industrial ecology – where the outputs of one industry are used as the inputs in another. Leveraging market value from the corridor network nevertheless requires that there is an arena where information can be gathered, understood by firms, interpreted, and turned into action. Achieving this is quite challenging. The corridor defines the geographical space in which resources can be managed.

Scholars involved in industrial ecology research examine the multiple human interactions that shape material exchanges and flows of matter and energy in cross-fertilization (Boons & Howard-Grenville, 2009; Cerceau, 2013). Such social imbrication relies on 1) multilevel cognitive mechanisms, 2) structural mechanisms, and 3) spatial and temporal mechanisms. Spatial dimensions are given, and temporal imbrications, though they are complex, can be managed by attracting investors. Structural interweaving describes the structure of global social interactions, such as how information circulates around networks to shape flows of goods and energy. From that point of view, the split of the governance structure between the three development councils reduces the capacity of the organization to identify cross-fertilization opportunities. However, multilevel cognitive interweaving with regard to corridor transformation may arise within Haropa, thanks to the port communities' federation, SeinePort Union, created in 2016. SeinePort Union, which unites the ports of Le Havre, Rouen, Gennevilliers, and Paris, represents a designated space for port communities to exchange information. Social interweaving could then derive from gradually denser interactions where similar representations and understandings of the corridor would emerge as new norms to frame decision-making and new types of economic exchanges. Social interweaving would then complete the geographical space and formal structure to foster interactions and the sharing of skills, knowledge, and networks. Interviews with port union leaders show that port communities share Haropa's objectives and intend to contribute to the corridor's transformation. The "no net land take objective" is also taken into account by attracting brownfield investments in former industrial chemical premises, as well as through the coexistence of housing, commerce, or leisure within industrial port areas where citizens oppose the arrival of industrial firms. Each port union plays their part in making contact with citizens, mayors, or locally elected representatives to promote port benefits and reconcile conflicting interests. Nevertheless, the interviews carried out show that competing forces are still at work between port unions, and the liability of foreignness remains quite costly in certain ports.

Horizontal, vertical, and sideways structures are also designed to enable interactions along the length of the corridor, and community networks are established to support the port transformation. Cognitive interweaving does not seem to have taken place yet, and the interviews conducted indicate that any new scheme still needs the port to get involved to some degree, which limits the benefits of grouping the port communities and highlights the port's role as a community builder. Specific services dedicated to gathering and processing relevant information at the corridor level need to be created to foster interactions and collaboration between firms and with the port authority.

Critical interdependencies also arise in land use concerns. Port land is typically used for terminals, handling operations, shipping, transportation, energy production, or industry. Port authorities must both attract new investors by providing land and support the setting up of a new consistent business ecosystem. They act as brokers, connecting land seekers with port area space, ecosystem, and logistics opportunities. Working at the scale of the corridor increases the chances of land availability and the visibility of interdependencies within the corridor. In the context of land scarcity and the "no net land take" regulation – according to which land must be recycled and new land take must be offset – working at the scale of the corridor offers a wider array of possibilities with regard to compensation. However, the rules for land compensation are not settled yet, and it is not clear how far the land compensation must be from the land take. If compensation can be achieved at an interregional scale (Haropa spreads over two administrative regions), then it widens the array of compensation possibilities. If not, the situation stays as it was before. As a consequence of land scarcity, port authorities may also seek land beyond port boundaries within the metropolitan areas they interact with to expand their throughput. Given their common interest in contributing to local development, Haropa needs to work in close connection with the different metropolitan development agencies to fully benefit from the economies of scale and scope.

Synergies do not appear spontaneously, and teams within the different ports must be trained to acquire a corridor mindset, as opposed to their former local mindset, to encourage the emergence of inter-local connections in the relevant areas. They must acquire knowledge of different port characteristics and service offers in order to become skilled at identifying and promoting infrastructure or service synergies. New corridor–port characteristics must be promoted beyond port boundaries to metropolitan authorities; a variety of intercity working groups; and local, regional, or national investment agencies attracting foreign or national investors. Though port–city relationships may have previously existed on a local basis, the integrated corridor scale significantly improves the prospects of the various cities, which can now draw on new arguments to attract businesses. Institutional relatedness is then aimed at boosting port reputation and opportunities. With regard to land management, the geographical information systems (GISs) that characterize (in terms of size, accessibility, neighbouring businesses, need for depollution, type, etc.) and locate all available land must merge to supply a picture of the corridor port area. Depending on their characteristics, some pieces of land may require depolluting investment or development before they can be handed to a new company. A piece of land may be qualified for lease or used for compensation purposes in the context of the net zero land take regulation.

Industrial ecology typically implies that each player acquires knowledge of the community of stakeholders to which they are linked (Cerceau, 2013). Since the impact and cost of transport are significant dimensions of material and energy exchanges between firms, industrial ecology tends to develop at a local scale within industrial parks. Nevertheless, increased variety among corridor players also multiplies opportunities for interaction and cross-fertilization.

A corridor-sized port authority as a lever to sustainably expand current product lines and markets

For most businesses and governments, environmental adaptation and decarbonization do not imply less business. The underlying policy of "green growth" is that of ensuring output remains at a constant and acceptable level while minimizing the input of resources. Indeed, the expansion of current product lines and markets does not preclude offering more environmentally friendly services that will eventually replace carbonized businesses. Parola et al. (2018) describes port authorities as hybrid organizations that are disassociated from operational activities and port services provision but still play a decisive role in managing business clusters. Ports may directly (though not always) invest in cold ironing (or onshore power supply), bunkering services, or carbon capture solutions. However, wind and solar power plants, additional waterway terminals that lead to new services and throughput, wind-powered freight services, and rail services all improve the environmental performance and attractiveness of the corridor with little direct involvement from the port authority, beyond providing amenities, space, and access. Still, the port authority can leverage its influence to foster innovation and throughput by showcasing its marketing and entrepreneurial capacities.

Port authorities are directly connected to only some of their users, namely those that are located within the port area and the customers with which they interact. Yet, port communities give port authorities indirect access to complete supply chains.

Lavissière et al. (2019) consider that port community network dynamics gradually involve formerly latent and isolated resources that are activated as the community evolves and becomes more complex.

An organization capable of gathering information on all port users can better identify greening opportunities and exploit combinations of skills, knowledge, and networks. In the past, French ports have suffered from low attractiveness and limited competition in calls for tenders. However, by issuing targeted tenders for environmentally friendly services, provided the basic infrastructure is in place, ports could see an increase in the number of competitors applying, which could ultimately drive service innovation.

Attracting new firms

Greening the corridor economy may require attracting new businesses that align with the evolving ecosystem. This can help to safeguard future business opportunities and to fill the gaps created by the disappearance of former inter-business connections and support. To successfully integrate new businesses into the evolving ecosystem, port development services need to design a strategy and select specific industries that will contribute to this transition. When reasoning at the scale of the whole corridor, facilitating the process for potential investors might also require having a single point of contact or establishing close relationships between the various possible points of contact within the different areas along the corridor. A corridor-wide policy on land use and rules needs to be set up to help port authorities and other players to understand their latitude and scope for action, which again requires coordination across the entire corridor. As land "readiness" and suitability are key factors in attracting investors, ports may choose to repurpose land, potentially for depolluting activities. Establishing a new business on land previously used by an industrial investor represents a perfect opportunity: there is no new land take, so no compensatory land needs to be found. Unfortunately, brownfield sites typically have neighbours and surroundings that give rise to acceptability issues. In spite of the legitimacy gained by authorities or firms, Haropa still needs to improve its relationship with citizens along the corridor. This may be what Haropa is currently missing: a strong relationship with citizens would give more legitimacy to establishments related to the port. The dotted circles in Figure 16.1, which represent citizens, show there are few formal spaces in which citizens can learn about port-related issues, except for at Haropa's Port Centre in Le Havre. Consequently, it will be important to establish these formal spaces for discussion in other parts of the corridor.

Conclusion

The corridor port authority benefits from increased legitimacy and extended influence to improve efficiency, deal with interdependencies, and safeguard future business, while still reducing carbon emissions. It is therefore logical to establish a corridor port authority. Our findings show that size and specific corridor features

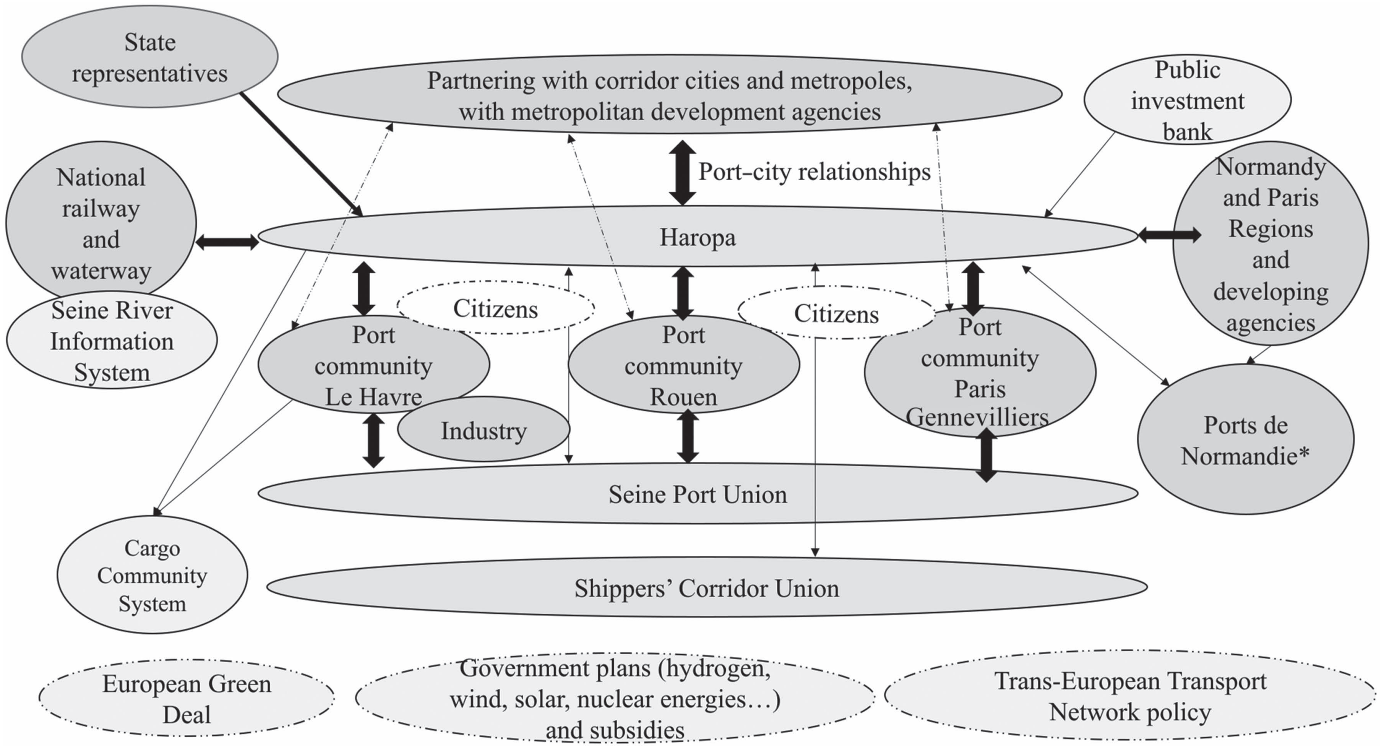

Figure 16.1 Institutional relatedness of Haropa with corridor players and stakeholders.

Source: *Ports de Normandie unites smaller ports in Normandy (Cherbourg, Ouistreham, Dieppe).

have different effects. While size alone gives greater legitimacy to the port authority, corridor reach gives it an unprecedented ability to deal with interdependencies. Putting these advantages into practice, however, requires that an effective strategy is designed to establish the necessary connections. It is also important that management and employees are trained to adopt an entrepreneurial corridor and environmental mindset.

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17 Resilience, adaptation, and adaptability

The impacts of climate change on river corridors

Clément Lavigne and Sébastien Dupray

Introduction

Since maritime flows play a crucial role in sustaining economies, the ability of ports and corridors to secure supplies and revenue for both citizens and industries is vital. As climate change may severely impact ports and their supply chains, some countries have turned their attention to the issue of port and supply chain vulnerability in relation to climate change. Unsurprisingly, many countries leading the way on the subject are those that are the most concerned: the United States with the recurrent hurricanes (Hallegatte et al., 2007, 2011), Japan and the 2011 tsunami (Akakura et al., 2015), the Netherlands with their vulnerability to water level rise (Siegel, 2020), and the United Kingdom with its dependency on ports as an island (Shaw et al., 2017, 2019). In France, the subject has only recently gained more attention (Caude, 2022), potentially because of the country's temperate climate, or because it relies more heavily on land than water logistics. However, even in countries where a considerable amount of research has already taken place, academics warn that stakeholders are still insufficiently prepared to address the impact of climate change (Becker et al., 2012), which suggests that there is still a need to disseminate knowledge. But increased vulnerability is not the only outcome of climate change for ports and corridors. Indeed, climate change has also pushed ports and corridors to adapt to port users' evolving behaviours and own adaptation, particularly in terms of energy use. Our approach to discussing the impact of climate change is therefore twofold: first, we review some of the key aspects of the ways in which ports and corridors have adapted to protect maritime flows and populations, and then we examine how ports must also adapt to align with the evolving behaviours of port users and stakeholders.

Port and corridor resilience and adaptation to climate change

Building on an ecosystem perspective, resilience is often defined as the ability of an entity or system to recover from a disturbance or disruption (Rodrigue et al., 2022). "Resilience here is understood as whether or not and to what degree and in what time frame a spatial unit can return to its pre-shock position and level

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of output or employment" (Pike et al., 2010, p. 3, commenting on the economic equilibrium-based framework). From an engineering point of view, resilience focuses on the study of vulnerability to hazardous events and their social and economic impacts. Adaptation measures are then considered in view of the assessed risks and impacts, which is the perspective we will adopt in this paragraph.

Adaptation or adaptability is usually considered the means by which resilience can be achieved. While adaptation involves a preconceived plan, adaptability refers to the dynamics that unfold in the face of unforeseen changes (Pike et al., 2010). Adaptation or adaptability, which relies on the actions taken by actors, can explain the geographical diversity, variety, and unevenness of resilience patterns. Adaptation thus refers to having a preconceived plan with which to face forthcoming disruptive events, and to the steps that must be taken by multi-actor authorities to improve port and corridor resilience.

Corridor adaptation

In research on port resilience, maritime ports are described as "complex operational systems with many different types of stakeholders, for example shipping lines, terminal operators, harbour operators, harbour masters, storage firms, cargo processors, passengers, local residents, transport firms and logistics service providers" (Shaw et al., 2019, pp. 253–254). These findings in relation to ports also apply to corridors. Corridors are a complex system of territories, infrastructures, and services dedicated to transport and logistics. Activities are supported by a wide range of infrastructures that serve the shipping business, such as maritime or estuarine access channels, harbours, oil depots, quays, docks, and waterways, including locks and canals. But ports and corridors are also logistical interfaces that require goods to be handled, stocked, dispatched, and transported from or to the hinterland. This process involves appropriate services, equipment, and infrastructures, such as waterways, railways, pipelines, and road facilities adapted to the goods, and thus demands millions of euros' worth of capital investment. Infrastructures are mainly public, although not exclusively, with long-term financing models. They were generally devised decades ago, when climate change was not yet a consideration in design or construction. Infrastructure is localized (quay, dock, locks) and linear (waterways, railways, motorway, communication networks), forming a system that can be disseminated along corridors, with variable degrees of integration with local territories and communities. It can sometimes constitute landmarks, or even social and cultural heritage. Each piece of infrastructure has a range of equipment in place to assist in carrying out logistics activities, such as cranes, connections, and transport monitoring. However, this equipment tends to have a shorter lifespan than average and a higher risk of becoming obsolete due to constant innovation and the development of new services designed to respond to client expectations.

Progressive sea-level rise is generally mentioned as an emblematic example of the consequences of climate change on the coastline and on maritime or estuarine assets and activities. Scholars insist that each port is unique and that there is no "one size fits all" solution that could be implemented across all ports (Becker et al., 2012). Similarly, consequences within a single corridor are highly location dependent. For instance a large maritime port, a smaller neighbouring port, a river port, and a railway terminal may all depend on different dynamics and thus require a tailored response. Moreover, both average and progressive sea level rise, and the extreme sea levels caused by more frequent storms, must be accounted for.

Phenomena brought about by climate change take a number of forms, and their direct and indirect consequences increase the overall vulnerability of corridors. Drought may directly impact the navigability of waterways; changes in temperature and salinity have an impact on sedimentary processes and may affect water quality and increase the need for dredging; and intense rainfall may impact logistics activities or even physically damage road and railway infrastructure. In certain geological situations, severe underground water table depletion, as well as salt water intrusion, will reduce water availability and even generate competition for access to water resources. Other climate change impacts include temperature extremes that could affect the functioning of vehicles or how cargo is handled (i.e. more refrigeration or air-conditioning units may be needed) (Becker et al., 2012).

In their 2009 study, Becker et al. (2012) conducted an interesting survey of port authorities across the world. They found that most ports were ill-prepared to face climate change risks. The ports surveyed had a short-term planning horizon (5–10 years) compared to the lifespan of port and transport infrastructure, which officially ranges from 30 to 50 years but is usually up to 100 years. Very few ports had plans in place to protect the port, and the authors found no correlation between the ports having plans and their actual level of risk. In the survey, 69% of respondents felt their port would be able to handle the expected sea-level rise without building additional protections (see UNCTAD's map [Asariotis, 2021] on seaports' exposure to water rise). Although the survey was conducted in 2009, the planning horizon, the perceptions identified, and the low level of cooperation within port communities, and consequently within corridor communities, all point to the ports' unpreparedness with regard to future risks. Following their work on British ports, Grainger et al. (2017) stressed that ports were insufficiently safeguarded from crises and that there was a long list of things that could go wrong. Doing nothing is regarded as unrealistic, regardless of our ability to reduce emissions in the future.

Climate change adaptation and mitigation

Facing these risks involves building defences (e.g. sea dikes, sea walls), possibly implementing a managed retreat (i.e. relocating people and businesses), and adapting to mitigate or eliminate risk and vulnerability (Siegel, 2020, Chapter 1, p. 1). At the time of preparing this chapter, there is no national or international prescriptive standard or code for climate change adaptation. Nevertheless, the experiences of various ports are now available. In the past, a distinction has often been made between climate change adaptation and mitigation. However, they are actually closely connected, especially when it comes to the development of corridor infrastructures, equipment, and services, which must be able to respond effectively to adaptation and mitigation in order to optimize these objectives. Mitigation implies changing practices and introducing innovations, the unit cost of which will drop as they become more widely used.

Although many publications, such as those of the European Environment Agency or the US National Ocean service, provide data on climate change, all experts agree that averages do not make much sense at a local level. Relevant local information on local climate phenomena is needed to adequately model and assess the exposure of a territory and guide decisions to anticipate consequences, plan, and implement appropriate measures. However, experience shows that choosing the relevant climate scenario, as well as downscaling global climate change consequences, is challenging. Furthermore, due to the inherent uncertainty of the climate projection, efforts should focus not only on collating baseline information on the future climate but also on including extreme events. Typical actions are therefore not only structural but also include: observing and collecting environmental data, improving our understanding of complex hydro systems, setting-up early warning systems, and developing organizational methods for non-standard situations. Uncertainty should be accounted for in decision processes, and the robustness of an adaptation strategy sometimes needs to be tested by simulations. It is important to determine the vulnerability of the various assets and services in relation to both the direct and indirect effects of climate change. Due to the functional dependence within the corridor, there may be significant cascading effects. To determine the level of consequences, which makes risks unacceptable, and to identify the relevant adaptations, options, and measures, it is imperative that a proper risk assessment is carried out. With worldwide data available on infrastructure adaptation experiments, adaptation plans can combine short-term and long-term action in a portfolio of actions addressing a number of vulnerabilities. The British Port Association's report (2021) proposes to focus on the adaptation of long-term infrastructure.

Becker et al. (2012) insist that the scientific community, policy makers, engineering support, and port authorities need to take an active role in improving their understanding of the wider context and in implementing adaptation strategies. PIANC membership, which includes major multinational companies in maritime public works, shows that cooperation with infrastructure builders is also needed to find, put into action, and disseminate solutions. At the corridor level, other skills may be needed, such as in the fields of transport (rail), electrical, or internet infrastructure. In France, in collaboration with the scientific community, public authorities have taken steps to estimate the local effects of climate change and sea level rise on ports. A relatively accurately map of the Seine corridor was published in 2020, which showed how sea-level rise and overtopping may affect ports, transport infrastructure, connections, industrial or stocking premises, and populations all along the river. The highest risks are not necessarily for the port itself but rather go beyond the port to the populations, industries, and transport segments that are impacted. This paves the way for targeted action. The way these risks should be dealt with, defining and facing the amount of investment needed to protect assets, and the issue of sharing this investment between private and public players when industrial players (and Seveso-graded industries) are at stake, are all barriers that need to be overcome. Still, the risks are now visible, thus enabling decision-makers to develop new approaches to tackling them. Several large-scale meetings have since taken place at the corridor level, bringing together researchers, private and public decision-makers (mayors, community leaders, planners, etc.), and the general public. Localized industrial associations in industrial areas can help to find collective and shared solutions. Public technical support is available to help, and local community plans are being set up. In addition to the usual weather forecasts and establishing local levels of risk to prepare populations and businesses, emergency/alert systems are being developed to improve resilience to unexpected events.

More effort must be made: local climate models still need to be improved; more simulation training is needed within port and corridor communities to investigate the potential domino effects of events along the supply chain; and efforts are needed to design and plan alternative paths and ports that can be used in the event of a crisis (Akakura et al., 2015) by using real-time multimodal simulators and port network capacity simulations. Given the cost of adapting infrastructure and the uncertainty as to where and how climate change impacts may arise, designing more flexible and interchangeable service routes for national economies could help to ensure an acceptable level of service even in the face of disruption. The same goes for Europe, which currently has no plan for dealing with the potential unavailability of key infrastructure and is lacking up-to-date and accurate knowledge with regard to business flows. In France, however, the lack of a legally defined or commonly accepted set of potential events does not encourage actors to take steps to define adaptation strategies. There is also a need for key infrastructure builders to acquire more knowledge on port and corridor challenges in order to be able to propose innovative solutions. Finally, drawing on the work of Kim et al. (2021), in addition to preparing for and facing the events, we must not forget the recovery plan or, better put, the reconstruction plan. On the whole, actors who are engaged in developing adaptative strategies try to reduce the vulnerability of the corridor's components while also improving its overall resilience.

Adaptation to improve port and corridor stakeholders' own adaptation

As key infrastructures serving the European economy, ports and corridors face other climate change impacts in relation to their stakeholders.

Shipping

Services requested by port users include fuel. Traditionally, shipping activities have relied on well-equipped harbour infrastructure, which is able to deliver fuel for ships in a timely and cost-effective way. This has been made possible by the development of oil depots and bunkering stations or ships, which have been taken for granted as a normal part of the harbour infrastructure. In return, these facilities have been a significant source of income for harbours, thanks to the passage fee paid and the presence of the depots.

In 2022, the global fleet stands at 100,000 ships, half of which are merchant ships. In addition to running on heavy fuels, these ships consume the greatest amount of energy. The regulatory framework for shipping, established by the International Maritime Organization, aims to reduce carbon intensity by 40% by 2030 and by 70% by 2050, before eventually reaching net zero emissions by the end of the century. Regarding energy provision, several pathways to decarbonization can be identified: 1) from traditional liquid fuels to hydrogenated vegetable oil (HVO) and fatty acid methyl esters (FAME), and finally to bio-based fuels; 2) from fossil liquefied natural gas (LNG) to biogas/biomethane and e-methane; 3) fuels based on green hydrogen used directly or as a base for the production of e-methanol or e-ammonia; and 4) electricity and battery storage. While CMA-CGM, a French container transportation and shipping company, chose LNG and testing hydrogen, the Danish company, Maersk, is moving to e-methanol. Meanwhile, the German company, MAN Energy Solutions, is developing a hydrogen engine.

Some of these technologies are inter-compatible (see “Facing the challenge”) and do not require major engine or storage capacity overhauls. They can therefore be seen as part of an industrial continuum, which offers some form of stability to investment. However, different fuels require different types of port infrastructure, and one of the challenges of the energy transition will undoubtedly be the multiplicity of fuels that coexist and potentially compete for infrastructure, space, and financing. Due to the international nature of the maritime industry, governments seem to have left it to the maritime sector to decide on what options would be best for decarbonizing the industry. Many harbours, both big and small (for leisure and fishing vessels), are now faced with the uncertainty of a potential change in demand. Depending on the design of zero-emission vessels, harbours are now expected to provide LNG, hydrogen, or ammonia, all of which require dedicated storage tanks and refuelling arms/infrastructure. Hydrogen needs to be densified and can be stored either in a liquid or solid form (compressed) with specific storing designs (Kunowsky et al., 2012). The new fuels may also involve new safety risks all along their supply chain, which could impact port premises and industries, as well as neighbouring populations. Ammonia is both toxic and corrosive and must be made safe within the storage space, bunker stations, and the ship’s engine room.

With no standard international agreement, small- and medium-sized ports will find it costly to offer a full range of energy stocks, and some port calls may be driven by the availability of specific fuels. According to the International Energy Agency, ammonia will account for around 45% of the global energy demand for shipping in 2050. However, in the European Maritime Safety Agency’s 2022 report on ammonia, the authors state:

> [T]he toxicity challenges and related risks are significant and, while manageable, they will add complexity to ship designs (compared to those for conventional and other low-flashpoint fuels and gases) and will potentially limit the ships for which it is a suitable fuel. Ammonia ultimately may prove to be a more appropriate solution for deep-sea cargo ships rather than short-sea, passenger, or inland waterway crafts.
>
> (European Maritime Safety Agency, 2022)

The report's authors also question the medium-term availability of green ammonia, in light of competing industrial needs. Although research into adequate engines is still ongoing, as Europe's major bunkering port, the port of Rotterdam has committed to developing green ammonia terminals, storage, and bunkering services, in addition to providing the other fuels (LNG, biofuels, etc.). Antwerp is preparing to provide ammonia bunkering too. Rotterdam is also the most important energy port in Europe, handling 13% of European energy demand. Given the European need for green hydrogen to sustain the energy transition, Rotterdam plans to import and distribute green hydrogen in the Netherlands, Belgium, and Germany, thus replacing previous oil flows through numerous industrial partnerships (bunkering companies, ammonia facility builders) and commercial agreements to provide hydrogen (Algeciras, Norway, Australia). In the short run, most new ships are being fuelled by LNG as an energy transition solution, which could mean that LNG will account for 40% of the shipping fuel market by 2050 (source: ENGIE). The ports of Le Havre and Marseilles are also currently investing in LNG bunkering.

Since the Glasgow COP26, uncertainty over the evolution of fuel demand and required infrastructure has given rise to the notion of "green shipping corridors" as a transition solution. These are meant to help companies scale up fuels, technologies, infrastructure, business models, and rules and regulations. Green corridors are specific shipping routes where the feasibility of zero-emission shipping is boosted by a combination of public and private actions. Green corridors support the use of energies other than LNG and require ports to make a joint commitment to enabling fully green shipping to emerge, based on robust and coherent infrastructure, along given shipping routes. This concept has been promoted and the summary report endorsed by various actors from the port and shipping world, such as port of Antwerp, port of Rotterdam, Maersk, NYK Line, and Rio Tinto.

With regard to river or sea shipping and the corridor-wide impacts, another concern is the requirement to provide cold ironing and onshore power supply. Such facilities not only demand local investment but also rely on electric grid infrastructure, which may need upgrading.

Energy to navigate the corridor and green the industry

In addition to supporting the energy transition in the shipping industry, port, corridor, national, and European players (industry players, cities, agencies, associations, energy providers) are coming together to facilitate the shift in other domains. Hydrogen is considered an opportunity to decarbonize industries and promote green transport modes, such as for trucking, shipping, barges, and air transport. Sea or river ports are often home to industries that are major users of hydrogen (refineries, iron and steel) or grey ammonia (phytosanitary industry). These account for 75% of the industries identified as needing to be "greened" according to France Hydrogène, the association working to develop the hydrogen industry. Obvious synergies can be found for the production and use of hydrogen in port areas. Hydrogen can be transformed into methanol from captured carbon from industrial premises to feed new maritime or transport needs and to ease energy transportation flows to consumption areas. Due to the presence of energy production, port areas and corridors also have an abundance of heat, favouring high-temperature electrolysis, and a high number of pipelines which, when abandoned, can be converted to or rehabilitated for hydrogen use.

Ports and corridors are also dense in traffic, whether for passengers (cruises, ferries, buses) or freight (trucks, trains, barges) and are located in or near cities that need to improve their own environmental impact. Port and corridor areas are therefore likely to become major hydrogen production and consumption zones in a type of circular economy. For example a hydrogen production and distribution project is currently being planned in Le Havre to meet clean city transport needs as well as clean local truck transport flows to and from the port and other local needs. The largest and most advanced green hydrogen plant (Air Liquide/Siemens Energy) in France, with a capacity of 200 MW, is set to open by 2025. It will be located next to the major refining and chemical complex in the port of Jerome, along the corridor from Le Havre. Meanwhile, the energy companies Total and ENGIE have joined forces to supply Total's bio-refinery, La Mède, located near Marseille, with green hydrogen using solar power. In Rouen, a zero-emission mobile barge, developed to service ships through hydrogen-fed cold ironing, should be in action by 2025. A similar barge is set to be used on the river in Paris. In these cases, ports have less direct control over bringing about the necessary changes, and ports' concerns are incorporated into wider national and European concerns. Port and corridor transformations rely on national government plans (i.e. the French recovery plan) or European plans, and on the ability of key industrial players to enter consortiums and develop partnerships with other players to address the changes that need to be made.

Facing the challenge

Financing these new models and insuring these new risks often demand an in-depth review of the existing frameworks. Valuing these new logistic or manufacturing chains and understanding and valuing new commercial or technological risks all require new skills which can be gained through active training or recruitment programmes. It is also important that ports share knowledge and innovation and cooperate when carrying out projects. In the meantime, the paths towards the transition can be envisaged by breaking actions into three categories: no-regret actions, low-regret actions, and high risk/high reward actions.

No-regret actions

These are actions that are selected because they have immediate cost benefits. They address the issue at hand and do not involve hard trade-offs with other policies. For example a set of initiatives can be taken by ports, infrastructures, and corridors in the area of digitalization. Such initiatives will, in all cases, respond to demand and can be gradually expanded. They allow time to make sure that existing data is collected in the right format, before possibly increasing the number of sensors, developing IoT solutions, and automating data tracking and connection between databases. Other no-regret initiatives may involve adapting piers, quays, or infrastructure to address the challenges posed by climate change and sea-level rise. Indeed, as it is now considered highly likely that these phenomena will take place, such initiatives respond to a long-standing trend and meet an immediate need. While it may be that not all extreme weather resilience measures need to be taken instantly, a review of the key risks, at the level of the whole corridor, may help to prioritize the actions that should be taken. A comprehensive adaptation of the quays, to respond to future changes in the energy mix, should be compatible with the work already done. Other changes may be carried out in anticipation of legislation, such as for cold ironing.

Low-regret actions

Low-regret actions are relatively low cost, and, based on likely future economic and climate projections, they are expected to provide benefits. In the area of shipping, emissions (3% of worldwide greenhouse gas emissions) are expected to grow due to the development of maritime routes for transportation and insufficient regulation. In this context, several pathways to decarbonization can be identified, some of which are considered low-regret actions. For example one route may be to move from LNG to biogas/biomethane and, at a later stage, to e-methane as proposed earlier or to move from hydrogenated vegetable oil (HVO) to fatty acid methyl esters (FAME) and finally to upgraded bio-based fuels. These solutions do not require major technological upheaval. Other routes are more capital intensive due to the need to update ships' and ports' technology. These include routes that use fuels based on green hydrogen directly, methanol, e-ammonia, or electricity and battery storage.

This set of measures highlights the multiple paths to decarbonized maritime transport and the challenge faced by shipping operators, harbours, and corridors when it comes to selecting the right technology. In this context, the coordinated approach of the green corridor for shipping could also be seen as a low-regret action, as it involves many actors making a joint commitment to using a particular technology and developing an integrated supply chain approach, meaning that they share both the risk and associated opportunity.

High risk/high reward actions

These actions, which can have higher stakes and risks, contribute to preparing for future situations. They can also offer additional social, economic, and environmental benefits. Some of the typical high risk/high reward actions that are being launched by a number of ports around the world involve a profound transformation of port facilities to accommodate multiple types of energy. Not only industrial facilities, refineries, and other fuel production sites but also storage tanks and berthing piers will need to be reorganized. Dedicated refuelling ships for LNG and other fuels, which will have to be built and operated, require specific know-how and generate new risks. Examples of such initiatives can be found in the strategic plans developed by various harbours such as Rotterdam, Antwerp, or Bilbao.

These plans generally provide a complete overview of a multiplicity of new fuels, an integrated logistics plan with the hinterland, and highly digitalized information networks to improve the traceability and efficiency of the supply chain.

Conclusion

In this chapter, we have tried to paint a picture of the major challenges that ports are facing and to show the need for technical and organizational innovation, as well as for raising awareness and training. We have also highlighted the breadth of interdependencies that require multilevel cooperation. Within the port and shipping industry, a more competitive setting is emerging where groups of players are trying to establish their rules. With regard to shipping, various shipping decarbonization initiatives exist, which aim to unite multiple actors and often work closely with large shipowners to help them prepare for future propulsion modes (Institut pour la transition eco-énergétique du maritime, Global Logistics Emissions Council Framework, Global Centre for Maritime Decarbonisation, etc.). In terms of maritime public works, the formerly niche area of maritime engineering is set to become a widely sought-after skill.

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18 Building a legal framework for the production and use of hydrogen in transport and logistics

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Introduction

Transport accounts for a quarter of the EU's greenhouse gas (GHG) emissions, and this number is growing. The European Commission estimates that to achieve climate neutrality as set out in the European Green Deal,[1] emissions from the transport sector will need to be reduced by 90% by 2050, which requires the transport and logistics sector to revolutionize its energy model. As a fuel, energy carrier, and storage solution, hydrogen is one of the options favoured by Europe to contribute to this energy transition in the medium and long terms. This transition will require an adaptation of the technical regulatory framework for the production, storage, transport, and use of hydrogen in propulsion systems.

European and French hydrogen strategies

European strategy

The European guidelines over the last 20 years have promoted both the fight against climate change and sustainable economic growth.

In line with the European Green Deal, which aims to make Europe the first climate-neutral continent by 2050, a new European climate law was adopted in July 2021.[2] It sets an interim target of reducing GHG emissions by at least 55% by 2030 (compared to emission levels in 1990). As buildings and transport are, together with industry, the main consumers of energy and the main sources of emissions, decarbonizing these sectors is a priority for Europe.

With this in mind, on 14 July 2021, the European Commission proposed a legislative package (called "Fit for 55"[3]) comprising 12 proposals which are currently being discussed with the member states. These new laws aim to increase the mandatory share of renewable fuels used in the member states,[4] to modify the energy taxation rules to promote renewable energies, to reconsider the tax reductions and exemptions that currently reduce the taxation of fossil fuels,[5] to strengthen the obligations of the member states with regard to the establishment of infrastructure for alternative fuels,[6] and to extend the emissions trading system to maritime and road transport.[7]

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It was after the presentation of the European Green Deal that new European strategies were proposed by the European Commission for industry[8] and mobility.[9] As regards energy, it proposed an EU Energy System Integration Strategy[10] and put forward an option for hydrogen by adopting a Hydrogen Strategy for a Climate-Neutral Europe.[11] This strategy identifies the challenges and opportunities for the development of clean hydrogen and presents a roadmap that will encompass the entire hydrogen value chain: innovation, market, production, transport, uses, etc.

According to this strategy, the share of hydrogen in the European energy mix should increase from the current 2% to 13–14% by 2050. To achieve these goals, the European Commission has set out a progressive trajectory for renewable hydrogen, the production of which will reach 10 MT by 2030 (40 GW of electrolysers). This energy transition will take place over three phases: in the first phase, it will replace the carbon-based hydrogen currently used (e.g. in the chemical industry); in the second phase, it will expand to other sectors such as the steel industry, heavy goods vehicles, rail transport, and certain maritime transport applications; and in the third phase (by 2050), it will extend to all the sectors that had been difficult to decarbonize up until that point.

But the tension over the EU's energy supply, following Russia's invasion of Ukraine in February 2022, has forced the European Commission to reconsider its energy policy. Following a communication on "Joint European Action for More Affordable, Secure and Sustainable Energy,"[12] the REPowerEU plan[13] (Figure 18.1) presented on 18 May 2022 aims to rapidly reduce European dependence on Russian fossil fuels (gas, oil, and coal), in particular by accelerating the massive expansion of renewable energies (45% by 2030 instead of the 40% provided for by the Fit for 55 package).

This reduction of our dependence on fossil fuels relies in particular on the use of renewable hydrogen, and the REPowerEU plan presents the European ambition to accelerate this transition (hydrogen accelerator concept), in particular by adding 10 MT of imported renewable hydrogen to the 10 MT planned to be produced in the EU by 2030 (target set by the Hydrogen Strategy for a Climate-Neutral Europe).

More specifically, with regard to the use of hydrogen in transport, the revised Renewable Energy Directive (RED) (2018/2001/EU) sets the share of renewable fuels in final energy consumption in the transport sector at a minimum of 14% by 2030. It provides that, for the calculation of this minimum share, member states may take into account renewable liquid and gaseous transport fuels of non-biological origin (RFNBO), which are considered renewable when the hydrogen component is produced by an electrolyser that uses renewable electricity.

Under the REPowerEU plan, two Delegated Acts complementing the RED are being prepared. The first Delegated Act[14] will establish a methodology for the production of these RFNBO. In particular, it will indicate the conditions under which hydrogen will be considered as "renewable." The second Delegated Act[15] will establish a minimum threshold for GHG emission savings from the use of recycled carbon fuels and will set out a methodology for calculating GHG emission savings from RFNBO and recycled carbon fuels.

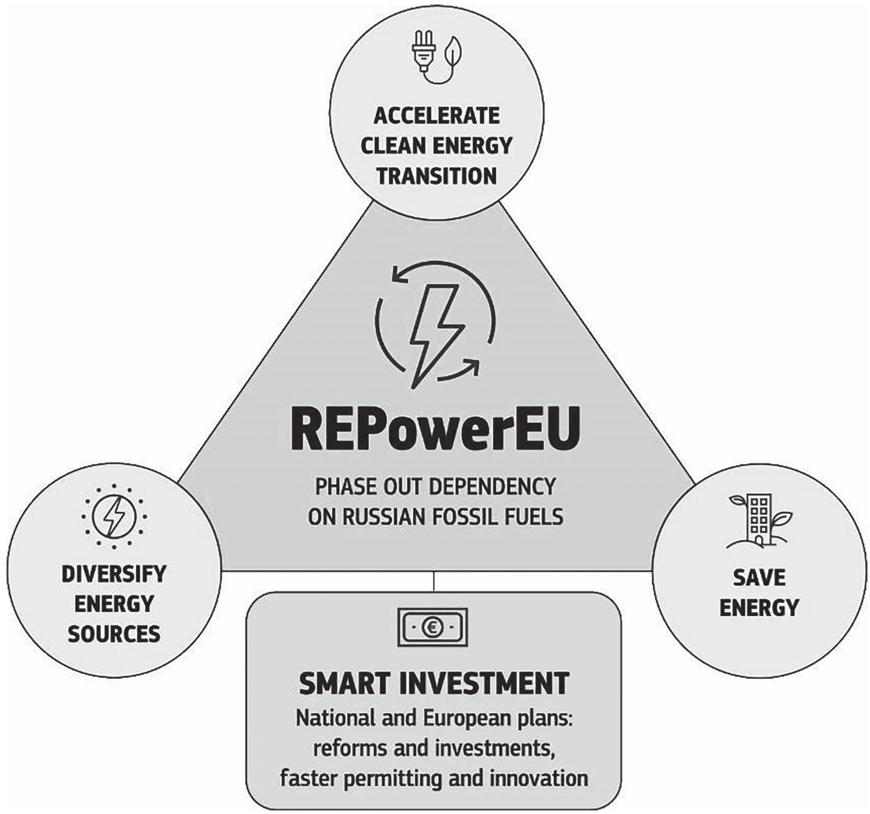

Figure 18.1 The RePowerEU plan. Photograph by the author.
Source: Plan REPowerEU COM (2022), 230.

Also, in accordance with the hydrogen accelerator concept, and to accelerate the projects' development, the European Commission will contribute a further €200 million to the Horizon Europe investments in the Fuel Cells and Hydrogen Joint Undertaking in order to double the number of Hydrogen Valleys.

Funding schemes for this transition are being put in place. Hydrogen systems and technologies are now recognized as a strategic value chain paving the way for an Important Project of Common European Interest (IPCEI). An IPCEI is a label given by the European Commission to very large industrial cooperation projects involving several member states. Having this label allows the project to benefit from an exemption from the rules on state aid. Fifteen projects located in France were thus proposed to the European Commission for the IPCEI label in March 2022, including the project to build a renewable hydrogen production plant in Port-Jérôme-sur-Seine (Seine-Maritime department), using 200 MW of electrolysers, for industrial and mobility purposes. This project, called "Hy2Use," was the second IPCEI to be validated by the European Commission. It was validated in September 2022.

With regard to the financing of hydrogen projects, one of the major challenges for France was to ensure that the production of hydrogen by water electrolysis using nuclear energy was recognized by the EU taxonomy for sustainable economic activities.[16] In July 2022, after much heated debate in the European Parliament, fossil gas and nuclear energy were finally included in this green taxonomy. This was a crucial victory as the taxonomy determines whether an economic activity can be considered environmentally sustainable, which has a significant bearing on how environmentally sustainable an investment is judged to be.[17]

Finally, the Guidelines on State Aid for Climate, Environmental Protection and Energy (CEEAG) were amended in January 2022 to bring them in line with the objectives of the European Green Deal and the Fit for 55 legislative package. They now support the energy transition in transport by deeming state aid compatible with the internal market for a number of categories of environmental protection and energy measures, such as for the acquisition and leasing of new or second-hand "clean" vehicles; for the retrofitting of vehicles ("the retrofitting, refitting and adaptation of vehicles"), in particular when this operation enables them to be considered as clean vehicles; and for the deployment of recharging or refuelling infrastructure, in particular for hydrogen.

French strategy

Through its 2019 Energy-Climate Law,[18] France has retained its target of reducing GHG emissions by 40% between 1990 and 2030 but aligned itself with the European objective of carbon neutrality by 2050.

It was one of the first European states to decide to explore the hydrogen route, via its Hydrogen Deployment Plan for the Energy Transition (2018). In 2019, France began to mobilize the industry and transport sectors by concluding Strategic Sector Contracts[19] (e.g. in the new energy systems, rail, and automotive sectors) and Commitments for Green Growth,[20] particularly in the road and inland waterway transport sectors. The adaptation of technical regulations has begun with, in particular, the creation of ICPE (Installations classées pour la protection de l'environnement) (Installation Classified for the Protection of the Environment) sections dedicated to hydrogen forklifts (Section no. 4715 in 2015) and hydrogen refuelling stations (Section no. 1416 in 2018).

In 2020, France resolutely embarked on the hydrogen path with the publication of a National Strategy for the Development of Low-Carbon Hydrogen in France. This strategy is of an unprecedented scope and aims to provide stakeholders with the visibility and support they have been demanding for years. Its objective is to support the production of low-carbon hydrogen through water electrolysis from low-carbon (i.e. nuclear) or renewable electricity.

In line with this French Strategy, an order[21] was adopted in February 2021 to establish a framework for the creation of a hydrogen market. In particular, it defined the three categories of hydrogen (renewable, low-carbon, and carbonaceous), created a traceability mechanism for renewable and low-carbon hydrogen (traceability guarantees and guarantees of origin), and set up a support mechanism for the sectors producing renewable or low-carbon hydrogen by water electrolysis. To be effective, however, these mechanisms are still awaiting the adoption of implementing legislation.

This national strategy was accompanied by the creation of a National Hydrogen Council (Figure 18.2). The Council indicated that, given the projects underway and the targeted uses, the consumption of decarbonated hydrogen would be concentrated primarily in seven major industrial basins in France, one of which encompasses the Seine Valley, including the Seine-Maritime and Seine-et-Marne.

At this stage, let us underline the advantages of the territories around the Seine Valley for the production, distribution, and use of renewable hydrogen. These advantages include, among others: a maritime coastline and agricultural activities conducive to the production of renewable energy; an industrial complex that consumes hydrogen (chemicals, refining); maritime and river ports oriented towards

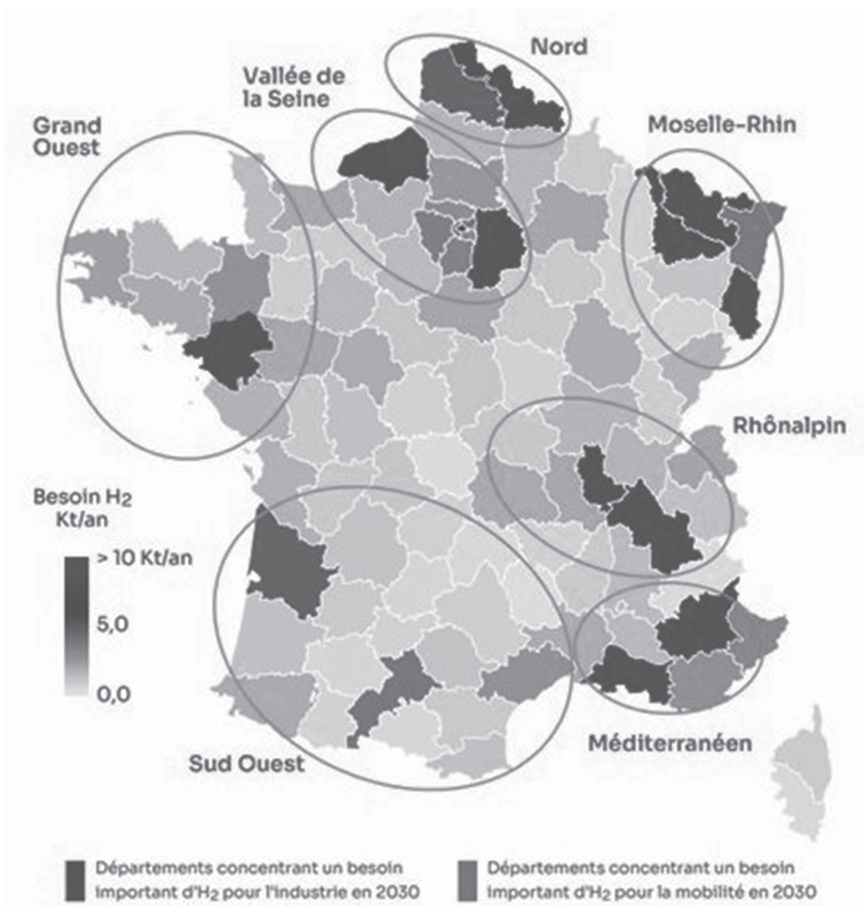

Figure 18.2 Major hydrogen-consumption basins in France.

Source: France Hydrogène, Trajectoire pour une grande ambition hydrogène, September 2021.

the energy transition of maritime and river mobility; and port and logistics warehouses that are potentially producers and users of hydrogen.

The required changes to the technical regulatory framework

Achieving the target inputs of the national Hydrogen Strategy will require adapting the technical regulatory framework to the deployment of hydrogen via innovative projects, whether for the decentralized production of hydrogen (e.g. production of renewable hydrogen by warehouses equipped with photovoltaic panels), its distribution to different users (companies, local authorities), or its use by different categories of vehicles (lorries, forklift trucks, handling equipment, refuse collection vehicles, boats, ships, etc.).

Hydrogen production and storage

Hydrogen production and storage facilities are subject to the regulations of ICPEs, notably:

- Section no. 3420,[22] which deals with the production of hydrogen: authorization required for the first molecule produced;
- Section no. 4715,[23] which deals with the storage and use of hydrogen: declaration required between 100 and 999 kg; authorization required from 1 t; Seveso low threshold authorization required from 5 t; Seveso high threshold authorization required from 50 t.

With regard to the production of hydrogen, Section no. 3420 was initially created to regulate the manufacture of hydrogen in "industrial quantities" from hydrocarbons and for processes with pollutant emissions (steam reforming). This regulation, which stems from the problem of chronic risks in the industrial environment, now seems unsuitable for the production of small or medium quantities of hydrogen by electrolysis (non-polluting), particularly for mobility (e.g. 300 or 400 kg/day for a distribution station).

The French Ministry of Ecological Transition confirmed in an administrative note[24] that when the production process does not present any particular challenge, it is possible not to judge a production as being in "industrial quantity" even if the product is marketed. For example the manufacture of hydrogen by water electrolysis could – depending on the volume of water consumed and the pressure on the water resources of the sector concerned or the energy efficiency of the device – not be covered by Section no. 3420. This administrative doctrine therefore allows the authorization system to be waived on a case-by-case basis by referring to the notion of pressure on the environment and imposing the declaration with control (DC) system on the site, subject to carrying out an impact study on water resources and the electricity network (prefectoral decree of special requirements adapted to each site). However, this case-by-case interpretation, based on a simple administrative note, seems to lack legal certainty insofar as these principles are not clearly set out in the regulations or more specifically in Section no. 3420, which only provides for the authorization regime and not the DC regime.

An adaptation of the ICPE regulation for the production of hydrogen by electrolysis (declaration or registration regime according to the quantities) would be desirable as it would benefit decentralized and non-industrial hydrogen production sites using electrolysis (e.g. refuelling stations, warehouses producing hydrogen by electrolysis powered by photovoltaic panels).

Hydrogen distribution

For the time being, only the distribution of hydrogen in refuelling stations for road vehicles is being developed. As this is a new use of hydrogen, the regulatory framework has been adapted thanks to the creation of a specific ICPE Section in 2018 (Section no. 1416[25]). Improvements are being made to this Section as feedback is received from stakeholders, encompassing both the requirements applicable to public multi-fuel stations and those applicable to stations that solely distribute hydrogen to captive fleets such as hydrogen bus depots. The regulatory regime planned is the DC regime, which is less restrictive in terms of instruction time compared to the authorization regime. Consequently, hydrogen-refuelling stations can be deployed with a shorter instruction time.

However, these hydrogen distribution sites, especially when hydrogen is produced on site, are subject to a set of requirements and insurance obligations that are often considered excessive by stakeholders in comparison with those imposed for the distribution of other fuels. The rapid development of regulations specifically dedicated to the production and distribution of hydrogen at multi-energy stations or at other sites (ports, bus depots, logistics or industrial sites) would be desirable.

In particular, and for various reasons linked to the cost of installing fixed refuelling stations, solutions are moving towards the development of mobile stations that can be used to supply vehicles, rolling stock, or boats where necessary. This raises the question of adapting the regulations that apply to the road transport of such stations, which consist of a container filled with a cascade of interconnected gas cylinders. There also remains the issue of adapting the regulations for the temporary storage of hydrogen.

The experimentation of hydrogen-powered seagoing or inland waterway vessels also raises the question of refuelling them with hydrogen. There are no regulations on hydrogen bunkering (by hose). Where standards exist, they are specific to liquefied natural gas (LNG).

At the moment, experiments with hydrogen-powered inland waterway vessels use the “swapping” model, which consists of exchanging gaseous hydrogen storage modules (tanks at 300–700 bar) that are transported to the site by road.

The development of hydrogen propulsion engines will lead to a range of ways of refuelling boats to be considered: installation of distribution stations on the quayside or on a floating pontoon, production of hydrogen on the quayside or delocalized production with hydrogen being transported by pipeline or by vehicle (tube trailer or tanker truck), and refuelling of the boat directly from the truck (unloading by hose to the boat's tank) or by handling the modules stored in the truck.

With regard to the installation of hydrogen-refuelling stations on a logistics or port site, the only existing regulation is that applicable to vehicle filling stations (ICPE Section no. 1416 and AMPG of 22 October 2018[26]). As this regulation is not specifically adapted to seagoing or inland waterway vessels, the operation of such an installation can be governed by an Arrêté de prescriptions spéciales (APS) (prefectoral order of special requirements) taken on the basis of Article L. 512–12 of the Environmental Code. However, if we wish to develop maritime and river hydrogen mobility, it will be necessary to adapt the regulations to specifically address the refuelling of ships and inland navigation vessels.

The energy transition in mobility thus requires the deployment of adequate infrastructure for alternative fuels. Currently, European regulations on hydrogen infrastructure coverage are not very restrictive, but they are set to be updated in the medium term, since, in application of the Fit for 55 package, the AFI (Alternative Fuels Infrastructure) Directive[27] will be replaced by a Regulation (AFIR[28]). This regulation, which will contain clearly binding obligations that must be applied directly by the member states, provides for the establishment of a minimum number of public hydrogen stations by 31 December 2030. These stations should be able to serve both light and heavy vehicles.

In France, support for the financing of such infrastructure could be increased, for example, by including it in the Certificats d'économies d'énergie (CEE) (Energy Savings Certificate) scheme, as has been done for shore power infrastructure. This system is based on a three-year energy savings obligation imposed by the public authorities on energy suppliers (the "obligated parties"). They are thus encouraged to actively promote energy efficiency among energy consumers: households, local authorities, and professionals. This system makes it possible to finance certain actions in all sectors of activity, including transportation, as long as they are included in the standardized operation sheets defined by decree. The scheme thus makes it possible to finance the installation of shore power supply infrastructure to supply electricity to ships or river boats in port.[29]

Hydrogen transport

The regulatory framework for hydrogen transport depends on international and European regulations which have been adapted to the different modes of transport to varying degrees.

The transport of hydrogen by so-called "land" modes (road, inland waterways, railways) is regulated by European texts (ADR,[30] ADN,[31] and RID[32]) applicable to intra-European and national transport by virtue of Directive 2008/68/EC, supplemented in France by the decree of 29 May 2009, on the transport of dangerous goods by land (TDG decree).

Hydrogen must be transported in suitable receptacles. Pressure vessels, including closed cryogenic vessels, are covered by the Pressure Equipment Directive (PED)[33] and the Transportable Pressure Equipment Directive (TPED).[34]

The access of vehicles carrying hydrogen to tunnels is subject to restrictions resulting from the ADR and the national tunnel classification.

For inland waterway transport, only the transport of hydrogen in packages is allowed (dry cargo vessels), not in tankers (ADN regulation).

The maritime carriage of gases or fuels with low flashpoints,[35] such as hydrogen, was originally prohibited by the International Convention for the Safety of Life at Sea (SOLAS). Exemptions were adopted for ships carrying gases in bulk with the adoption of the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code). As this code does not contain any requirements for the carriage of liquefied hydrogen in bulk, the IMO developed Interim Recommendations for the Carriage of Liquefied Hydrogen in Bulk[36] in 2016. These include the provision of a portable hydrogen detector for each crew member working in the cargo area, the installation of fire detectors to detect any hydrogen fires, and appropriate safety measures to avoid the formation of an explosive mixture in the event of a hydrogen leak.

Hydrogen propulsion

With regard to the use of hydrogen for propulsion, while many experimental projects are emerging in Europe and France, the associated technical regulatory framework is only just being developed.

As far as road vehicles are concerned, the type-approval and circulation of hydrogen-powered vehicles are possible from a regulatory point of view,[37] but the regulations have yet to evolve, in particular with regard to the approval of hydrogen-fuel-cell-refrigerated trailers. In particular, work is underway to define the risk control measures necessary for the transport of dangerous goods using hydrogen-powered vehicles and to assess the risks associated with driving or parking in confined spaces (tunnels, underground car parks, etc.).

French regulations have authorized the retrofitting of vehicles since 2020[38]: it allows a vehicle with an internal combustion engine to be converted into a battery or fuel cell electric vehicle.

For seagoing and inland waterway vessels, the regulatory framework for the approval of hydrogen-powered vessels is being developed at the international and European level.

For the maritime mode, the International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels (IGF Code) developed by the IMO came into force in 2017. This code contains requirements for the arrangement, installation, control, and monitoring of machinery, equipment, and systems using low-flashpoint[39] fuels. However, these regulations currently only contain rules for LNG used as a fuel. Rules for other low-flashpoint fuels, such as hydrogen (fuel cells), methyl/ethyl alcohols, or low-flashpoint diesels, are expected to be added as they are developed by the IMO. Work is currently underway, and interim guidelines for the safety of ships using fuel cell power installations are being developed. In the meantime, the

IGF Code allows the use of other low-flashpoint fuels, including hydrogen, provided they have been approved on the basis of an alternative design, the assessment of which is governed by the SOLAS Convention.

The technical requirements for inland navigation vessels (river barges, pusher barges, tug boats) are based on the standards developed by the Comité européen pour l'élaboration de standards dans le domaine de la navigation intérieure (CESNI) (European Committee for Drawing Up Standards in the Field of Inland Navigation), which regularly adapts the European Standard Laying Down Technical Requirements for Inland Navigation Vessels (ES-TRIN). The ES-TRIN has been adapted to LNG and electric propulsion, but not yet to hydrogen. The CESNI set up a temporary working group in 2020 to prepare draft technical requirements for the use of fuel cell systems on board inland navigation vessels. The expected proposal will also address fuel storage on board vessels and the distribution and processing of fuels (in particular methanol and hydrogen). As a result of this work, the ES-TRIN is expected to be amended in 2023 for entry into force in 2024. In the meantime, national authorities may nevertheless apply to the international bodies (CESNI or the Central Commission for the Navigation of the Rhine [CCNR]) for a derogation, in accordance with Article 25 of Directive (EU) 2016/1629, Laying Down Technical Requirements for Inland Waterway Vessels.

In the absence of established standards, these alternative risk-based approval processes involve high costs and long delays that are not compatible with the objectives to decarbonize transport.

In France, experiments with hydrogen solutions on board inland waterway vessels have been permitted since 2019, thanks to a change in the regulations ("Restricted Navigation Zone Decree"[40]) which allows the Prefect to authorize innovative projects for navigation limited to part of the national territory.

The incentive framework for the hydrogen transition

Measures are gradually being put in place to help transport and logistics players make the transition to alternative engines or fuels, particularly hydrogen.

Aid for the purchase of new "clean" vehicles

The "accelerated depreciation scheme" ("*suramortissement fiscal*," Article 39 decies A of the Code général des impôts [CGI]) allows companies subject to corporate income tax or personal income tax to deduct a percentage of the original value (excluding financial expenses) of their investments in vehicles (trucks, buses, coaches, vans) that use exclusively one or more alternative energies. In 2019, the accelerated depreciation scheme was opened up to electric or hydrogen-powered vehicles. The acquisition of hydrogen-powered heavy or light commercial vehicles is aided by this scheme, which can be combined, since the 2021 Finance Act, with the "ecological bonus."

Aid for retrofitting of inland waterway vehicles, vessels, and ships

Retrofitting is the operation of converting a vehicle's engine to reduce its carbon emissions. Given the cost – and especially the unavailability on the market – of hydrogen-powered vehicles, ships, or boats, retrofitting has the advantage of facilitating the energy transition of the existing fleet.

With regard to vehicles, financial assistance for electrical retrofitting has existed since 2020 (*prime au rétrofit électrique*), but it only applied to passenger cars, vans, or two- or three-wheeled motor vehicles and motor quadricycles, excluding heavy vehicles. A regulatory change adopted by decree on 26 April 2022, now makes retrofits to vehicles in categories M2 and M3 (vehicles for transporting people, including buses and coaches) and N2 or N3 (vehicles for transporting goods) eligible for this bonus. This change therefore completes the system of aid for the energy transition of heavy vehicles, which previously only encompassed the acquisition of new vehicles (ecological bonus and accelerated depreciation scheme).

Since 2020, the retrofitting of seagoing and inland waterway vessels has benefited from the accelerated depreciation scheme (Article 39 decies C of the CGI). Under this scheme, aid is available for new equipment for the main propulsion or the production of electrical energy. This aid may help to facilitate the use of hydrogen in particular (acquisition of fuel cells, hydrogen storage, or compression equipment).

Following its "Retrofit" study carried out in March 2021,[41] the Agence de l'environnement et de la maîtrise de l'énergie (ADEME) (Agency for Ecological Transition) has recommended that the "accelerated depreciation" mechanism is adapted to retrofitting heavy vehicles – as has been done for the maritime and river sectors – to push the transition of the vehicle fleet towards more sustainable options. This recommendation is based on the finding that retrofitting is a less expensive way of achieving the energy transition for heavy vehicles.

Conclusion

As a partner in the DEPLHY Project (Déploiement de l'Hydrogène en Vallée de Seine (DEPLHY VDS)), IDIT has witnessed a nascent and growing interest in renewable or low-carbon hydrogen as a solution for decarbonizing industry and mobility among economic and public stakeholders. By adopting the first national Hydrogen Deployment Plan for the Energy Transition in 2018, France was a forerunner, followed two years later by the adoption of a European strategy. The climate emergency, coupled with the outbreak of war on the edge of Europe and its worrying consequences on the EU's energy supply, has accelerated European legislative progress in recent months. A whole regulatory arsenal is being created or adapted in order to establish the technical, economic, and regulatory conditions necessary for the creation of a value chain for the production and use of renewable or low-carbon hydrogen, and for players to launch themselves safely into the production and use of this energy. Replacing traditional energy solutions with new, sustainable alternatives disrupts the existing framework that has been in place for decades, thus making it a significant challenge that requires the rapid mobilization of a wide range of skills.

Notes

1 COM (2019) 640, 11 December 2019.
2 Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ("European Climate Law").
3 "Fit for 55": Delivering the EU's 2030 Climate Target on the way to climate neutrality, COM (2021) 550, 14 July 2021.
4 COM (2021) 557, 14 July 2021.
5 COM (2021) 563, 14 July 2021.
6 COM (2021) 559 and 560, 14 July 2021.
7 COM (2021) 551 final, 14 July 2021.
8 A New Industrial Strategy for Europe, COM (2020) 102, 10 March 2020; Updating the 2020 New Industrial Strategy: Building a Stronger Single Market for Europe's Recovery, COM (2021) 350, 5 May 2021.
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11 COM (2020) 301, 8 July 2020.
12 COM (2022) 108, 18 March 2022.
13 Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions: REPowerEU Plan, COM (2022) 230, 18 May 2022.
14 Commission delegated regulation supplementing Directive (EU) 2018/2001 of the European Parliament and of the Council by establishing a Union methodology setting out detailed rules for the production of renewable liquid and gaseous transport fuels of non-biological origin.
15 Commission delegated regulation supplementing Directive (EU) 2018/2001 of the European Parliament and of the Council by establishing a minimum threshold for greenhouse gas emissions savings of recycled carbon fuels and by specifying a methodology for assessing greenhouse gas emissions savings from renewable liquid and gaseous transport fuels of non-biological origin and from recycled carbon fuels.
16 Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment and amending Regulation (EU) 2019/2088.
17 Commission delegated regulation (EU) 2022/1214 of 9 March 2022 amending Delegated Regulation (EU) 2021/2139.
18 Loi no 2019–1147 du 8 novembre 2019 relative à l'énergie et au climat.
19 Contrats stratégiques de filières.
20 Engagements pour la croissance verte.
21 Ordonnance no 2021–167 du 17 février 2021 relative à l'hydrogène.
22 3420. Inorganic chemical manufacturing.
23 4715. Hydrogène (numéro CAS 133–74–0).
24 Ministère de la transition écologique. Note interprétative de la rubrique IR_180116 fab quantité industrielle sous IED, BNEIPE/BRIEC.
25 Section no. 1416: service stations – installations, whether or not open to the public, where gaseous hydrogen is transferred into vehicle tanks, the daily quantity of hydrogen distributed being greater than or equal to 2 kg/day.
26 Arrêté du 22 octobre 2018 relatif aux prescriptions générales applicables aux installations classées pour la protection de l'environnement soumises à déclaration sous la rubrique n° 1416 (station de distribution d'hydrogène gazeux) de la nomenclature des installations classées . . ..
27 Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure.

28 Proposal for a Regulation of the European Parliament and of the Council on the deployment of alternative fuels infrastructure and repealing Directive 2014/94/EU, COM (2021) 559, 14 July 2021.
29 Fiche n° TRA-EQ-124.
30 European Agreement concerning the International Carriage of Dangerous Goods by Road.
31 European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways.
32 Regulations concerning the International Carriage of Dangerous Goods by Rail.
33 Directive 2014/68/EU of the European Parliament and of the Council of 15 May 2014 on the harmonization of the laws of the Member States relating to the making of pressure equipment available in the market.
34 Directive 2010/35/EU of the European Parliament and of the Council of 16 June 2010 on transportable pressure equipment and repealing Council Directives 76/767/EEC, 84/525/EEC, 84/526/EEC, 84/527/EEC and 1999/36/EC.
35 Flashpoint is the lowest temperature at which a chemical can vaporize to form an ignitable mixture in air.
36 Résolution MSC.420 (97), 25 November 2016.
37 Regulation (EC) No 79/2009 of the European Parliament and of the Council of 14 January 2009 on type-approval of hydrogen-powered motor vehicles and amending Directive 2007/46/EC; Commission Regulation (EU) No 406/2010 of 26 April 2010 implementing Regulation (EC) No 79/2009 of the European Parliament and of the Council on type-approval of hydrogen-powered motor vehicles.
38 Arrêté du 13 mars 2020 relatif aux conditions de transformation des véhicules à motorisation thermique en motorisation électrique à batterie ou à pile à combustible.
39 The flashpoint is "the temperature . . . at which a product gives off sufficient flammable vapour to ignite" according to the SOLAS Convention (regulation II-2/3, §24). These fuels include all those with a flashpoint below 60°C, such as hydrogen used in fuel cells.
40 Article D.4220–4 of the Transport Code and Order of 20 August 2019 on the issue of navigation permits in a restricted navigation zone, JORF of 6 September 2019.
41 Conditions nécessaires à un rétrofit économe, sûr et bénéfique pour l'environnement, ADEME, March 2021.

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19 Are corridors a key asset for the deployment of short food supply chains?

Roland Condor and Claude Duvallet

Introduction

For over two decades, short food supply chains (SFSCs) have witnessed continued growth, bolstered by public policies encouraging the consumption of fresh, locally grown, and environmentally friendly products. However, this development falls short of the objectives put forward by local authorities. In France, for instance, achieving the objective of introducing more local produce into collective catering services has proven challenging, even though the situation does vary across different territories.[1] One reason for this is the difficulty that local food system actors face in building strong SFSCs that can handle a significant flow of products (Paciarotti & Torregiani, 2021).

We should therefore ask ourselves the following: what kind of SFSCs can be used to capitalize on the expansion of local produce markets? In this chapter, we argue that local stakeholders should aim to model their SFSCs on existing global food chains. One key source of inspiration could be the period following the Second World War, when economic actors in Europe had to build new infrastructures and corridors to manage the growing flow of products arriving from across the globe. As the local produce market continues to expand, using these existing infrastructures and corridors and envisioning the construction of new ones based on the same principles are key avenues for future development.

It would appear that, in the short-term, utilizing existing infrastructures conceived for global food chains (such as maritime ports, airports, railways, motorways, warehouses, and rivers) would prove overzealous due to the lower volumes exchanged at present, as well as the local nature of the market, which requires basic infrastructure to connect farmers with consumers. However, the massification of SFSCs is well underway. Indeed, to respond to geopolitical and climate crises, various cities and nations are examining the extent of their food self-sufficiency (Balembois et al., 2022; Zasada et al., 2019). Therefore, addressing the logistics issues surrounding SFSCs is crucial, as there is a need to increase the volumes of local food products, which may expand to areas beyond city borders. Offering immense scope to reduce the carbon footprint and transport costs of food production, global food chains can be powerful sources of inspiration and innovation. Even though logistics corridors are currently organized to optimize the international

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flow of goods (import/export of agricultural products), we believe that part of the existing infrastructure could be harnessed to transport local products that are not necessarily imported or exported and that complement imports.

This chapter is organized as follows: first, we will discuss the logistics challenges posed by the growing local product market and the ways in which these issues arise. Second, we will present how global food supply chains can provide inspiration for a more effective structuring of SFSCs. Finally, we will consider the potential benefits of disruptive technologies and corridors in enhancing the massification of local products, as well as their traceability.

The rise of local distribution channels: the bearer of new logistics challenges

It is clear that the logistics issues faced by SFSCs are a direct consequence of the expansion of the local food market. Though to some extent, the rise in demand for locally sourced products is consumer-driven, it is mainly the result of state- and local authority-led initiatives aimed at achieving greater levels of self-sufficiency.

The foundations of local food networks

Local food channels emerged in reaction to the globalized, financialized, and productivist agriculture that arose in the wake of the Second World War (Van der Ploeg, 2012). The aim was to find an alternative solution: an agricultural model that was more sustainable and less reliant on external inputs, as well as yielding products of high nutritional value and generating economic value for participating farmers (Paciarotti & Torregiani, 2021).

The current situation surrounding long food supply chains is a paradoxical one, whereby certain agricultural raw materials are sold to intermediaries who, in turn, may resell them to global agri-food firms. These firms will then process them in far-flung locations before reselling the finished products worldwide, including back in the area where the raw material was originally produced. These constant comings and goings raise doubts about the effectiveness of the current global agri-food system, as it suffers from clear inconsistencies in terms of flows (with products from distant lands being consumed while locally available products are overlooked; or with manufacturers overproducing and generating excessive food waste). The global agri-food system is equally a major generator of greenhouse gas emissions (Mundler & Rumpus, 2012; Pradhan et al., 2014) and contributor to the decline of rural territories due to the concentration of production infrastructures (McDonald, 2010). Health scandals, such as the mad cow disease or horse meat controversies, have further fuelled scepticism about these long chains. In some cases, these controversies have completely obscured the benefits of global food chains, such as the availability of diverse products at affordable prices; innovations in terms of flavour, smell, and visual appeal; and enhanced user-friendliness and ease of use – a key asset for the modern active household.

Local food systems have spread to all four corners of the globe. In their research study, Cleveland et al. (2014) show how American universities played an important role in the development of local food channels on campuses in the early 2000s. Since then, they have undergone countless innovations, including the introduction of basket systems in France back in 2001 and, more recently, the proliferation of digital platforms and vending machines in various French regions. The meaning of these systems has also evolved over time. In France, the notion of "circuit court" (short chain) has long been used, emphasizing the number of intermediaries involved in the supply chain, with a maximum number of intermediaries preferred over proximity. However, more recently, the term "local food circuits" has become increasingly more common (at least in France), emphasizing the importance of locality over the number of intermediaries. This shift reflects the recognition that a chain with only one intermediary may still fail to fulfil its founding missions if it benefits non-local actors.

Recent international events, such as the war in Ukraine and the COVID-19 pandemic, have hammered home the urgent need for greater food sovereignty. Although the pandemic has had a relatively minor impact on food trade, the war in Ukraine has demonstrated the vulnerability of some states and their reliance on specific countries for certain food items, such as wheat, maize, and sunflower products. This has sparked discussions about the current state of food flows. The quest for food autonomy has already driven a number of urban agriculture movements (Zasada et al., 2019), ushering in a new era of food supply development. Metropolises must, now more than ever, lay the groundwork for their own food autonomy, while taking care not to close off exchanges with other territories for the sake of resilience and access to a greater variety of products. Territories must therefore strengthen SFSCs without going as far as neglecting global channels and even combine the two whenever possible.

A growing market

The French market has seen a clear increase in the presence of local food networks. In terms of supply, there is a rise in the number of farms selling in short chains. According to the French Ministry of Agriculture, by 2020, almost a quarter of farmers will be selling their products in short chains, compared to 17.5% in 2010, representing an increase of nearly 6% in just ten years. This growth has been observed not only among small farms, particularly market gardens, but also among larger dairy or cereal farms looking to diversify their outlets to reach a more local customer base (Agreste, 2023).

In terms of demand, the French population is a major buyer of local produce. However, while many studies indicate an intention to purchase local products, surveys measuring actual consumption and trends over time are rare. Though there does appear to be a sustained movement in favour of buying local, this trend is hampered by factors such as the cost of these products and insufficient consumer knowledge, as well as underdeveloped distribution logistics (Paciarotti & Torregiani, 2021). Still, the rising number of farms offering local products and the emergence of intermediaries, including start-ups offering digital sales solutions, indicate a growing market for local food products.

That said, the most tangible demonstration of this growth can be found in public initiatives. Indeed, the pursuit of territorial self-sufficiency has led to various public policies favouring SFSCs. In France, these initiatives are implemented at both national and local levels. For instance the "Egalim law" voted in 2018 imposed a system of quotas for the proportion of so-called sustainable products in school canteens, thereby requiring them to purchase certified products, featuring specific labels such as: "Agriculture biologique (AB)" (Organic Farming), "Haute valeur environnementale" (HVE) (High Environmental Value), or "Appellation d'origine protégée" (AOP) (Protected Designation of Origin). In July 2021, the "Climate and Resilience Law" was passed, building on the measures laid out by the Egalim law to include private collective catering. Regional initiatives have also been implemented to promote the use of local supply chains, such as the "Je mange normand dans mon lycée" ("I eat Norman food in my school") campaign in Normandy, which encourages the consumption of locally sourced food.

The main objectives of such national and local initiatives are to offer a fresh and nutritious product selection, to create new markets for local farmers, and ultimately pave the way for greater food self-sufficiency. Unfortunately, these ambitious objectives are still a long way from being achieved. Although some regions have a relatively well-structured supply chain to stock their canteens, the situation is quite different in other localities, which could be partially explained by logistics problems.

Logistics challenges

For Paciarotti and Torregiani (2021), logistics issues represent one of the main challenges for SFSCs. Despite the growing demand and in some cases, the high availability of local products, it can at times prove difficult to match demand and supply. The authors identify several reasons for this, including:

- High prices resulting from the niche nature of the market;
- Limited variety and quantity of products available;
- Difficulties in supplying public institutions with suitable products, in terms of both quality and quantity;
- Organizational and coordination issues among local food chain actors, and even at the local food system level;
- High logistics and transportation costs compared to conventional distribution systems;
- Limited logistics and commercial organization;
- A lack of economies of scale due to the small size of farms;
- Lack of consumer information about product types and selling point locations;
- Problems accessing these selling points;
- Limited resources and lack of training for farmers in terms of marketing and communication activities;

- Limited expansion capacity for some small farms (land access issues); and
- The risk of staff burnouts due to small workforce size and the heavy reliance on key staff members to simultaneously perform various tasks.

This last point does not directly lead to logistics problems. However, when faced with continued growth and increasing demands to handle production, marketing, sales, and logistics activities, farmers are put under immense pressure. While many farms remain family-run businesses, and family members can be called upon in times of need, this system is only feasible up to a certain level of activity. Once local food businesses pass this point of development, farmers will need to recruit and manage an external workforce and then organize their supply chain accordingly. As a result, in the context of the rising growth of the local food industry, the adoption of new models of supply chains is needed, and farmers can turn to global food chains for inspiration.

Global food chains: a source of inspiration

According to Paciarotti and Torregiani (2021), the actors of local food systems can learn much from the logistics of long food supply chains when looking to improve their processes. However, putting such lessons into practice is not easy, nor is it particularly common. The authors therefore identify a number of innovative practices that could be developed elsewhere. These practices may be disruptive, that is not based on existing practices. One such approach is to adopt strategies observed in global food chains for use in SFSCs. By doing so, several strategies can be implemented to enhance the effectiveness of SFSCs.

Internalization, pooling, and delegation of transport services

To meet the growing demand for local products, producers may decide to internalize logistics activities, that is to invest in transport equipment (such as refrigerated trucks) and human resources to assist with order preparation and delivery. Nevertheless, this solution is only feasible if the farm is of a certain size, if the volumes handled are significant, and if a range of sales outlets is available – they cannot be limited to a single farm shop or a few nearby outlets, for instance.

Alternatively, producers can opt to pool their transport services with other farms or companies that supply the same geographical areas. Storage facilities, for instance, can be shared on farms with the necessary infrastructure to accommodate occasional storage. This pooling solution has the added benefit of optimizing transport costs and reducing carbon emissions. However, if flows are too high or if farmers want to have more room for manoeuvre, this solution can quickly become restrictive. This is especially the case when the producer handles transportation personally.

Finally, farmers can delegate product transportation or storage to a specialized service provider. This allows farmers to free up time for other tasks and to entrust the responsibility of certain activities to a third party, who will be an expert in this domain. Despite these advantages, our observations suggest that few farmers go down this route and tend to prefer internalization or resource-pooling solutions. Still, delegating logistics services to a third party can be an attractive solution for those who are not looking to invest heavily in equipment or recruitment campaigns and prefer not to handle these services directly.

The use of wholesalers

Farmers also have the option of selling their goods to wholesalers, who then sell them on to professional clients. This practice is particularly common in the collective catering industry, especially in schools, where wholesalers provide central kitchens with the necessary ingredients to prepare meals for users. The central kitchens managed by the institution (direct management) and supplied by wholesalers constitute the main logistics chain in this case. That said, another, less dominant chain consists of using catering companies, which provide meals ready for consumption without making use of the client's staff and equipment (concessionary management).

Up until recently, wholesalers have mainly sourced their products from food manufacturers. However, by ensuring that canteens incorporate a minimum amount of sustainable and organic products into the meals they provide, the Egalim law has brought about a shift in supply source management in school settings. Moreover, following measures implemented by local authorities, such as the governments of regions (the highest level of administrative division in France) or departments (smaller administrative divisions within a region) to promote local products, wholesalers have been urged to rethink about their supply chains by seeking out local food sources and setting up operations as close as possible to the end market. Today, wholesalers are forging genuine partnerships with local producers by supporting them throughout the production process.

Food hubs

Local food hubs are local logistics platforms dedicated to local food products, which have been hailed as an innovative process by researchers such as Paciarotti and Torregiani (2021). The logistics chain for local food hubs is as follows: farmers deliver their products to a dedicated platform and the platform staff then groups and allocates products ready for delivery to customers, most of whom form part of the catering sector. While this model has only recently begun to gain traction in European countries, it has been functioning successfully in the United States for several years. Studies indicate that the model saw significant development in the mid-2000s, following several pilot experiments in the 1970s (Cleveland et al., 2014).

This logistics model is designed to accommodate increasing flows without requiring farms to expand their facilities. Indeed, food hub platforms serve as a means to consolidate quantities, which can vary greatly from one producer to another, and help address the challenges associated with growth outlined earlier. These platforms act as an intermediary between producer and their customer, reducing the number of trips made by farmers and their time spent on the road. In addition, these platforms allow producers to save on fuel and delegate the responsibility for reducing the carbon footprint of their operations. Studies on food hubs show that their small size and close proximity to end markets make them highly agile: the platform's logisticians have direct contact with the farmers and have the necessary equipment to collect food from the farm in the event of unforeseen circumstances.

In terms of business model, most food hubs operate with a general interest mission, meaning that community funds contribute in part to their investments and operating budget. Rather than purchasing foodstuffs themselves, these platforms act as intermediaries, facilitating the transit of goods between producers and customers. However, the economic difficulties already outlined in literature highlight the need for careful consideration when it comes to forming business and governance models. Food hub operators must not rule out the possibility of single-partner governance (such as an agricultural cooperative) and aim to achieve a well-balanced budget that limits the use of public funds as much as possible.

Food hubs are facilities designed to handle local food products and so typically require the construction of dedicated infrastructure. However, it is possible to use existing global food facilities to create a local food hub. For example distributors have experimented with incorporating local food produce in their regular product offerings. Alternatively, farmers can establish food hubs on their farms. In short, actors can either decide to create dedicated infrastructure from scratch based on supply chain principles or instead opt for repurposing existing infrastructures. This is also a possible solution for wholesalers. In all cases, this combined or hybrid model offers improved cost control and a balanced investment approach. This economic advantage is crucial and demonstrates the immense value of building on existing elements of global food supply chains.

Although the establishment of food hubs may create the impression of creating distance between producer and consumer, in reality, they can actually help bring them closer together by enabling consumers to easily identify and connect with local producers who may be only a short distance away.

New logistics challenges for local products

The approaches outlined earlier are solutions that have been adopted by farmers or their stakeholders to tackle the challenges of growing local food chains. However, in the coming years, it is likely that local chains will function in a way similar to global chains and that we will see the use of previously unexplored corridors and technologies in local distribution channels.

The use of corridors

Logistics corridors, whose use has traditionally been limited to the mass transportation of goods, also offer avenues for the distribution of local products, as evidenced by the use of rivers as distribution channels. In an American report published in 2014, Day-Farnsworth and Miller explore the possibility of using the Mississippi river to distribute local farm products to cities along the river, as well as a distribution channel along the shores of the lake Michigan (Day-Farnsworth and Miller, 2014). While the precise outcome of this project remains to be seen, it highlights the role of rivers in SFSCs and the possibility of using existing infrastructures commonly used for mass market food distribution to improve SFSC operations.

In France, for instance, the Seine Axis logistics corridor (Paris–Normandy) could benefit greatly from adopting the approach outlined before. Paris, one of Europe's leading metropolises, lags behind when it comes to food self-sufficiency, as demonstrated by various studies published in French (Balembois et al., 2022). Therefore, like many other neighbouring cities in Europe, Paris has no choice but to seek out new food sources from further afield (Zasada et al., 2019). Meanwhile, the Normandy region is renowned for several agricultural products, such as dairy products, and boasts of two international maritime ports (Le Havre and Rouen), with the latter standing as the leading French port for cereal exports. The Normandy region is also home to a thriving seafood sector, thanks to its 600 km of coastline. The A13 motorway and the Paris–Normandy rail link facilitate the movement of passengers and raw materials between the two regions. The region's infrastructure network is therefore well suited for the supply of food products prepared within a 400-km radius of Paris (Cherbourg–Paris: 350 km; Le Havre–Paris: 200 km; Rouen–Paris: 130 km). Though several carriers already use the motorway to distribute Norman products to Paris, the climate and economic objectives put forward by local authorities urge local actors to explore new ways of collecting and distributing local food products. For example a number of French cities, including Paris, restrict the passage of polluting vehicles in certain areas, encouraging operators to build hubs outside the city centre and to use green modes of transport for the final leg of the journey.

The Seine Axis logistics corridor provides an example of how reorganizing flows and investing in development plans can benefit not only the territory receiving the locally produced goods but also the territory producing these goods, as well as the corridor itself. Food hubs should be established near the departure and arrival points of goods along the corridor. Agricultural production can also experience renewed growth around rivers by focusing on production methods that preserve water quality such as organic market gardening or orchards. Multimodal solutions, such as rail, trucks, or barges, can also be used to help achieve economic and CO_2-emission reduction objectives.

However, it is important to note that these changes should not disadvantage the producing region, which will also have its own self-efficiency objectives. Instead, a portion of international flows can be redirected to benefit both regions. For example in the case of wheat flows, a part of the wheat traded in the port of Rouen can be rerouted to the Paris region, which could then foster the creation of local feed mills for bread production. These suggestions can serve as inspiration for other cities which are looking to relocate their food chains and achieve greater self-sufficiency.

New information systems

In recent years, a string of scandals have eroded consumer confidence in the food industry. Examples include the Italian food company Buitoni, accused of being responsible for the death of two children due to a deterioration in the level of food hygiene control.[2] Similarly, Graindorge, a French company specializing in cheese production, was forced to recall its products on 5 April 2022, following a suspected case of listeria. Finally, Ferrero, a household name in chocolate and confectionery production, also had to recall certain products due to suspected salmonella contamination.

In the face of all these scandals, consumers are becoming increasingly conscious of exactly where food products have come from, as well as the tests and inspections they have undergone during the processing and transportation process. This increased traceability will foster greater consumer confidence, as it will eliminate the possibility of product falsification or misinformation (Puget, 2021).

Over the last few years, technologies have emerged that allow decentralized trust without relying on a limited number of entities. One such technology is the blockchain, which guarantees the immutability of information stored in completely decentralized registers. Originally introduced in the monetary sector in the wake of the 2008 financial crisis (the "subprime" crisis), this technology first appeared in response to the loss of confidence in banks. An unknown individual, or group of individuals, operating under the pseudonym "Satoshi Nakamoto," invented a new cryptocurrency called "Bitcoin" (Nakamoto, 2008). The underlying technology, the blockchain, gained further traction in 2014, when Vitalik Buterin developed the concept of Smart Contracts, which were developed by and implemented within the Ethereum Blockchain (Buterin, 2014). The use of blockchain technology has since extended beyond the financial domain, particularly in the field of logistics, allowing for document digitization and product traceability.

Blockchain technology, with its capacity to keep a permanent, unalterable record of transactions, offers a reliable means of tracking the journey of foodstuffs from point of origin to end user. This technology therefore stands as a powerful tool to bolster consumer confidence, provided it is integrated with Internet of Things (IoT) devices – physical objects that are connected to the internet and can collect, transmit, or receive data – across the supply chain. These devices will also need to be certified to ensure the reliability of the information sent to the blockchain. In the context of local channels, this integration allows for greater transparency in terms of the provenance of products, as well as enhanced levels of food safety. While blockchain technology cannot eradicate the risk of foodborne illnesses such as salmonella or listeria, it can help streamline the product recall process.

One particular theme that many local actors are focusing on is the logistics of short and local chains, since consumers are increasingly calling for greater assurance regarding the origin, as well as the transportation conditions in some cases, of the goods they buy. In the context of short or local channels, reducing the number of intermediaries, and therefore the amount of operations needing to be recorded, could serve as a viable solution. However, the degree of industry development must also be taken into account, as certain small-scale producers may lack the infrastructure necessary for such deployment. The formation of groups could perhaps help mitigate these challenges, just as shared logistic resources could also be envisaged in this case.

Conclusions and future research

The growth of local food channels is well underway, but to accelerate and streamline this development, actors of local food systems will need to establish efficient supply chains capable of handling both physical and informational flows. In this regard, long chains should not be viewed as rivals to shorter channels, but rather as sources of inspiration. The aim here is not to discount the contributions of local farmers in the success of local food networks, who work tirelessly to offer consumers high-quality and locally grown produce. However, as we look towards the future of supply chain development, it will be necessary to explore other distribution models that can accommodate increasing volumes of goods. This may involve testing out new approaches, including those employed by actors in long food supply chains.

Short and local food supply chains fall under the category of "alternative food networks," which aim to bring producers and consumers closer together, as well as provide scope for production relocation to meet the challenges of sustainable development.

Notes

1 https://ma-cantine.beta.gouv.fr/statistiques-regionales
2 www.capital.fr/entreprises-marches/affaire-buitoni-les-55-victimes-reclament-250-millions-deuros-a-nestle-1446469

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20 Automated deliveries

The future of urban logistics?

Jakob Puchinger

Introduction

Connecting producers with their end users, urban logistics and last-mile distribution are critical components of the supply chain. With the world's population on the rise, the volume of urban deliveries is hitting record levels, and global supply chains rely heavily on maritime transport for long-distance transportation of non-urgent goods. This chapter aims to discuss the future of urban distribution with a focus on robot-based last-mile deliveries. The connection to maritime ports is achieved through multi-tiered delivery systems linking ports via inland corridors, transshipment points, warehouses, urban consolidation centres (optional), and, finally, last-mile deliveries to customers.

In recent years, technological advancements have led to increased experimentation with unmanned aerial vehicles (UAVs or drones) and robots for last-mile deliveries. Some experiments have involved using drones for deliveries in suburban or rural areas from designated drone ports, for instance (Amazon Prime Air, 2022). Other companies have experimented with van-based drones to increase distribution efficiency in locations where delivery points are further apart than those found in highly urbanized settings (Stewart, 2017). Other experiments have been carried out using robots to deliver goods, with pizza delivery robots being one of the earliest examples (Davies, 2022). In urban settings, and in the wake of significant backing from investors, the topic of automated deliveries is increasingly coming to the fore. However, a number of major regulatory subjects remain unresolved (Biermann et al., 2021).

On examining the range of possible uses of robot and drone deliveries, it becomes clear that an extensive use of drones is not a viable option in densely populated areas, at least not for the foreseeable future. Slow-driving robots, however, have emerged as an interesting alternative in areas with limited access for vans and cars, as they are smaller, quieter, and more environmentally friendly than car- or scooter-based delivery solutions. Several experiments have already been conducted on university campuses and pedestrianized areas (Britt, 2019), and it is anticipated that many more similar experiments will be carried out in the future, as companies are drawn in by the prospect of boosting efficiency and bringing down costs by eliminating the need for delivery personnel. Recently, a new type of fast-food truck

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offering advanced levels of consumer interaction was tested out in Shanghai, which allows customers to order and pay for their food directly at the robotic vehicle (Wong, 2020). A recent review on automated deliveries in e-commerce sector (Rai et al., 2022) provides a detailed overview of this topic, including a focus on past and ongoing experiments, recent literature, interviews with major French actors and their insights, and a discussion of the impact of the COVID-19 pandemic.

This chapter will begin by providing an overview of urban logistics, last-mile delivery, as well as how they interact with maritime and inland ports. It will then shed light on the latest advancements in hardware and experimentation in automated deliveries. After that, it will delve into the environmental, legal, economic, and social factors associated with the introduction of automated delivery vehicles in urban settings. In addition, it will present recent research focused on planning robot delivery operations in cities. Finally, this chapter will conclude by proposing a forward-thinking vision for the future development of urban automated deliveries.

Urban logistics and maritime ports

More than half of the world's population currently resides in cities, and this number is set to rise in the coming years, with figures expected to reach almost 70% by 2050 (United Nations, 2018). In Europe, urban areas are home to more than 74% of the population (ibid.), and against a backdrop of increased traffic congestion, cities are faced with an ever-increasing demand for mobility. The steady growth of e-commerce and urban deliveries has brought about a fundamental shift in the urban logistics landscape (Dablanc, 2019). Persistent consumer demands for higher service quality and virtually instant deliveries, combined with a surge in delivery volumes, have severely disrupted urban freight operations.

In the wake of the COVID-19 pandemic, the demand for urban deliveries has risen even further (Dablanc, 2023), and the number of delivery vehicles in cities is expected to increase by 36% in city centres by 2030 (Pandemic, Parcels and Public Vaccination, 2021). In light of these changes, cities will need to regulate access to their central areas, with a particular emphasis on reducing local pollutants, traffic, and noise. This will, in turn, call for greater coordination in terms of resource allocation, including the development of delivery zones and the use of connected delivery vehicles, such as electric delivery vans, cargo-bikes, and automated electric delivery vehicles.

Larsen and Van Woensel (2019) provide an overview of urban logistics and deliveries in their 2019 work, which examines macro trends such as digitalization, automation, and e-commerce, as well as possible avenues for achieving more sustainable delivery practices. In their literature review on last-mile logistics published in 2019, Olsson et al. (2019) present last-mile delivery as a crucial operational component, ensuring the successful transportation of goods to the end customer or parcel pickup point. However, when implementing a last-mile logistics system, operators must also consider certain strategical and technical aspects, such as network design, warehouse locations, inner city consolidation centres, and fleet composition. As will be explored later in this chapter, the interplay between these various decision-making levels, technological advances, political decisions, and legislation, as well as customer behaviour and public opinion will all play a significant role in shaping the future of urban deliveries.

The connection between seaports and their hinterlands is a highly important topic, and it has already been widely discussed in literature. In a recent review by Witte et al. (2019), for instance, the authors discuss the research carried out over the past 30 years, demonstrating how the concept of so-called inland ports has seen a shift within global supply chains and that these ports have gone from having a passive "follower" status to taking on a more active "leader" role. Inland ports also play a key role in large cities, serving as important distribution centres and logistics platforms for the local area. In this vein, megacities have a vested interest in controlling certain logistics activities, and, depending on the policy and governance structure, inland ports can be a means for them to do so, as they can be controlled by the public sector. The situation in the Paris region is a clear example of how inland ports can be leveraged for this purpose (Raimbault, 2019). Furthermore, the merger of the maritime port of Le Havre with the river ports of Rouen and Paris (Haropa port[1]) in 2021 is equally a testament to the importance of the link between maritime logistics and cities.

When linking urban last-mile deliveries with maritime logistics, a series of strategic decision-making challenges arise. One such example is the recent case study presented by Bouchery et al. (2021), which examines the optimal location for dividing and unloading maritime containers into smaller shipments. The authors raise the question of whether it is more effective to perform such operations in close proximity to the seaport, or instead at an inland port. In response, the authors put forward a decision model and present a case study in Sweden, before concluding that using a hinterland port is typically the better option in this case.

Automated delivery vehicles

Automated delivery technology is a fairly recent addition to the logistics scene, and so design proposals and prototypical developments for new vehicles abound. Given the importance of sustainability and combatting global and local levels of pollution, the vast majority of such vehicles are battery-powered, eschewing traditional combustion engines. In addition, the use of electric drivetrain systems is also highly advantageous, offering smaller size, simpler design, and better motion control than their traditional counterparts. Currently, all of the vehicles hitting the market require remote control by a human operator, mainly due to unresolved questions surrounding liability. However, a recent study suggests that in the future, a single supervisor could oversee a fleet of 50–100 robots or about 10 automated mobile parcel lockers (Joerss et al., 2016). Robots usually rely on high-speed data connections, as they depend on ongoing map updates to operate safely. Current experiments show that mapping data are updated and uploaded just once daily (Brandt et al., 2019, p. 4).

The development of automated delivery vehicles will be shaped by their scope of use, with their areas of navigation – such as streets, cycle paths, pavements, or other pedestrian areas – acting as a major differentiating factor. Automated delivery vehicles operating on streets will be subject to the same legal and security requirements as those for passenger transport and will need to be able to merge into traffic flows and interact safely with other road users, including cars, pedestrians, and cyclists. Slower vehicles, in contrast, such as smaller robots operating on pavements and pedestrian areas only, may face fewer legal challenges as they pose less of a security risk. Currently, most companies developing automated delivery vehicles are focusing on pavement operations. Jennings and Figliozzi (2019) propose the term "sidewalk automated delivery robots" (SADR) for these vehicles, which can carry out delivery tasks from a sender to a recipient without human intervention. SADRs hold much promise for the future of distribution, as they are expected to yield faster delivery times and at a lower cost.

In their recent work, Baum et al. (2019) provide a systematic overview of the use of "automated-micro vehicles" in the context of urban deliveries. The authors categorize various vehicle concepts based on the necessary infrastructure (non-road and road), the vehicle type (automated bikes or delivery robots), and the human reference (autonomous or requiring human intervention). In addition to this classification, the authors analyse the major companies and projects offering such vehicles, providing a comprehensive overview of the current market landscape.

Delivery robots present several distinguishing characteristics based on their technical specifications, including their speed, size, weight, capacity, and range. Starship robots, for example, have a range of 6 km, a speed of 6 km/h, and a payload capacity of around 10 kg (Jennings & Figliozzi, 2019). However, in more recent press statements, Starship robots have been claimed to boast a range of up to 40 km (Lunden, 2022). The technical characteristics of these vehicles are evolving rapidly, especially in terms of battery capacity and automated driving capabilities. In their study, Jennings and Figliozzi (2019) provide technical details for various delivery robots, citing speeds ranging from 6 to approximately 55 km/h, payload capacities of 10–50 kilograms, and have ranges spanning 6–78 km.

A recent prototype developed by Mercedes-Benz offers an attractive new prospect for automatic delivery vehicles: a van capable of picking up new parcels, as well as recharging or replacing robot batteries where necessary (Burgess, 2016). An in-depth analysis of the operational planning of such a "mothership" concept has already formed the focus of various studies (Yu et al., 2020, 2022a, 2022b) and will be discussed in more detail later in this chapter.

Environmental aspects

Robot manufacturers, as well as the companies testing and using such novel delivery technologies, share a common goal: to reduce emissions while increasing overall system efficiency and bringing down costs. The energy consumption and emissions of road-automated delivery robots have been investigated in a study by

Figliozzi and Jennings (2020). The authors found that roadside delivery robots are set to offer greater efficiency in terms of energy consumption and emissions compared to SADRs. As is the case with delivery drones, it could be argued that due to their limited capacity, the use of additional warehouses required for these robots may offset these benefits and negatively contribute to life-cycle greenhouse gas emissions. However, it is expected that overall street travel distances and delivery times will be reduced, which should in turn mitigate associated externalities such as traffic congestion, CO_2 emissions, and noise pollution. Nevertheless, increased travel on pavements may give rise to new negative externalities and safety concerns, especially for pedestrians (Jennings & Figliozzi, 2019; Figliozzi & Jennings, 2020).

Social acceptance

Getting the general public onboard will be critical for the successful large-scale roll-out of delivery robots. This is especially the case for SADRs, and careful consideration of how and where these robots can coexist with pedestrians will be crucial. A recent master's thesis written by De Groot (2019) offers an in-depth examination of the acceptance of delivery robots by pedestrians and presents a technology acceptance model for delivery robots. This model primarily considers the perceived ease of use and usefulness of delivery robots, which have a direct impact on attitudes and levels of acceptance. Ease of use is based on the ability of SADRs to interact with pedestrians on the pavement. To this end, the author proposes the concept of "predictable manoeuvring" whereby pedestrians can anticipate the robot's movements. To determine this, researchers have used computational experiments to simulate the behaviour of robots and pedestrians, utilizing the social-force model, which is widely used in the field (Helbing & Molnar, 1995). The results of these studies indicated that robots should be perceived as "less dynamic" than pedestrians by moving and changing directions at a slower pace. This finding aligns with later conclusions in this chapter, which indicate slow robot speeds do not negatively impact operational efficiency (Yu et al., 2020). Other factors, such as perceived job losses, or the prevalence of sensory devices such as cameras and microphones on pavements, may also significantly impact levels of social acceptance.

One of the major challenges that needs to be addressed in robot-based deliveries is the final part of the delivery. Several options present themselves: customers may have to collect their order from outside their building; the robot may be able to drop off the order in an automated locker for the customer to retrieve at their convenience; or the robot might possess advanced technology that will enable it to enter buildings, climb stairs, and more. These questions surrounding the final stage of delivery remain largely unresolved. The National League of Cities (NLC)'s Center for City Solutions, a research and advocacy organization in the United States, has offered an interesting solution: that of combining robotic delivery vehicles with human porters for the final leg of the journey.[2]

Legal concerns

The deployment of automated vehicles, particularly robot delivery vehicles, presents a number of legal challenges. In their 2018 work, Hoffman and Prause analysed the regulatory framework for robot delivery vehicles. The authors found that, traffic law and regulations need to be adapted to account for these vehicles, especially with regard to liability issues. In many national legislations, a distinction is made between product liability and tort liability. In the case of robotic delivery vehicles, tort liability would arise from the failure to use or operate the product in accordance with the law (e.g. traffic law), while product liability would result from the robot not functioning correctly. Furthermore, most robot delivery vehicles require supervision and must be controlled remotely, at least in part, necessitating a continuous exchange of data between the robot and the control centre. This data will be collected by the robot through various sensors such as cameras, microphones, and light detection and ranging (LiDAR). This massive data collection is necessary for the operation of the robots, as well as for documenting accidents or other problematic situations. This raises privacy concerns that will need to be addressed if manufacturers are to comply with the various regulations in force such as the European Union's General Data Protection Regulation (GDPR). On one hand, the data related to the delivery itself is not problematic, as it serves a clear purpose – that of successfully delivering a product to the end user. On the other hand, delivery robots will also collect other forms of data, such as visual data and sound recordings, to provide evidence in case of accidents, for example. The data gathered may include the personal information of passers-by in the street, which will be collected and processed without their explicit consent. These issues will need to be addressed moving forward to ensure GDPR compliance. Hoffmann and Prause (2018) suggest using measures such as pseudonymization of personal data and data encryption as a possible solution.

The legal aspects under discussion also raise the question of policy, as laws and regulations are typically used to implement specific policies. Over the last few decades, the notion of smart cities, powered by technology, has emerged as a promising solution to many urban challenges. A prevailing technocentrism has led to a focus on reducing congestion and accidents, largely overlooking the quality of life of local residents (the emphasis on connected and automated cars is a prime example of this). However, in his recent book, Green (2019) puts forward the concept of a "Smart enough city," arguing that technology should be implemented "to address social needs and advance policy, rather than adapting goals and values to align with technology" (p. 159). As such, cities must carefully consider the role and place they wish to assign to automated vehicles as a whole, and automated delivery robots specifically, to ensure that they enhance, and not erode, the quality of city life.

Economic aspects and cost

In terms of costs and economic viability, the availability of relevant literature is relatively limited. Starship, for example, offers food delivery services on several college campuses in the United States, charging US $1.99 (Feldman, 2019) per delivery. However, the actual cost per delivery is estimated to be less than €1.00, considerably lower than the cost of equivalent human deliveries, which is highly dependent on local circumstances (Hoffmann & Prause, 2018). The cost of a robot-based delivery system can vary considerably, depending on the demand structure and logistics network design. Studies have demonstrated that by combining robots with vans, they can outperform conventional vans, though this will depend on the network structure and customer distribution (Jennings & Figliozzi, 2019).

Planning robot deliveries

In recent years, researchers have turned their attention towards exploring the potential operational benefits of using automated vehicles for urban deliveries. Bakach et al. (2021, 2022), for instance, have examined robot delivery operations centred around robot hubs. Yu et al. (2020, 2022a, 2022b), on the other hand, have focused on the various questions surrounding "mothership" models, that is where vans transport one or several delivery robots.

In their 2021 work, Bakach et al. examine a two-tier delivery network, whereby robots operate on the second tier and are based at robot hubs. These hubs are supplied by traditional vehicles such as vans or trucks. The authors propose a model and methodology to determine the optimal number of robots and hubs to efficiently serve a customer base, as well as comparing the operational costs of the robot-based system to those of a conventional truck-based system. Across various case studies, the results show that the new robot-based system offers significant savings on operational costs, ranging from 70% to 90%, depending on parameters such as robot speeds, driver wages, and customer time windows.

Yu et al. (2020) investigated the use of robots for second-level route deliveries in a two-echelon urban delivery system. The concept involves a mothership van carrying robots on the first-level route, dropping them off, and picking them up at parking areas, while the robots handle deliveries on the second-level routes. Only robots are authorized to deliver goods to customers, and pedestrian zones in city centres or campuses constitute the target areas for their deployment. The authors proposed mathematical models and specialized algorithms to model and resolve operational planning challenges. A sensitivity analysis was conducted using a large testbed of artificial test instances, with a focus on robot speeds. On analysing their findings, the authors recommended keeping robot speeds low to ensure a pedestrian-friendly insertion into the urban environment, as system performance gains were negligible with increasing robot speeds.

In addition, in their 2022 study, Bakach et al. examined the potential issue of sharing pavements with pedestrians. The authors suggested that it could be beneficial for the robots to avoid routes with high pedestrian densities, as this would improve the overall public acceptability of the system. In their study, the authors focused on a robot-based last-mile delivery problem that involves flexible path planning in zones with varying pedestrian flow densities. A model and specific algorithm are proposed in the paper, taking into account the stochastic travel times of the robots. Based on extensive computational experiments, the study demonstrated that considering varying pedestrian flow leads to alternative path choices in 30% of cases.

Yu et al. (2022a) have also studied a generic problem variant for van-based robots where robots and vans perform pickup and delivery operations in a city environment. In this study, the authors factor in restricted access zones in certain areas of the city, such as university campuses or pedestrian zones, which can only be accessed by robots. Vans can directly deliver to some customers, however, and can also drop off and pick up their robots at predefined parking areas, which also serve as locations for reloading the robots and swapping out their batteries where necessary. Using a case study of the city of Xi'an (China), the authors performed a comparative analysis of this approach with more traditional delivery approaches involving fixed robot hubs. The results showed that the mothership-based approach can be highly advantageous, resulting in a cost reduction of more than 10% in some cases, depending on the fixed cost setting of the hubs.

In another investigation by Yu et al., a comprehensive examination of robot battery usage and different recharging strategies was conducted (2022b), focusing on a two-echelon electric-van-based robot delivery system with en-route charging. The distinctive feature of this study was the prospect of recharging the robots while they are being transported in the vans, potentially saving time in comparison to systems where recharging is limited to specific parking areas. The authors present a model and a specific algorithm to perform a computational analysis. Through an analysis of various factors such as vehicle charging modes, charging rates, and maximum battery capacities, the findings revealed that en-route charging can lead to cost reductions in certain cases.

All this research points to the cost-effectiveness of implementing robot-based deliveries in the distribution process. The findings outlined in this chapter demonstrate that, from an operational standpoint, automated solutions can help bring costs down considerably in comparison with more conventional delivery approaches. This economic viability explains the growing interest for these new technologies within the distribution industry.

Conclusion and future prospects

The outlook for future technology advancements in automatic deliveries is a cautiously positive one, with promises of attractive cost reductions and reduced environmental impacts for urban deliveries. Still, as these robots begin to take to the streets, certain societal questions will inevitably arise, particularly with regards to the impact on urban landscapes, where space has already become a prized commodity. In addition, delivery robots may decrease face-to-face interactions – a laudable objective during the COVID-19 pandemic, but perhaps not so desirable for the future of our society. There is no shortage of proposals and discussions on the topic, including combining robots, vans, and other transport modes with human porters in densely populated areas. Though these robots offer clear advantages, it is worth remembering that wheel-based delivery robots may not always be able to ensure final delivery to the end consumer.

The rise in urban deliveries, both currently and in the years to come, risks to diminish the appeal of urban centres with local shopping options, which could change the face of our cities. Technological and operational advancements in robotic deliveries are expected to be significant, and, as with every technological leap, these developments will trigger economic and societal consequences that will affect the way cities function. Moreover, the interaction with longer-distance deliveries is predicted to play a crucial role in attaining efficient and sustainable urban logistics systems. New multimodal interactions are also anticipated. Cities with rivers passing through their central areas offer unique opportunities for such intermodal connections, enabling high-volume shipments to be delivered to the heart of the city while reducing inbound road traffic. In order to enhance the quality of life in urban areas by minimizing traffic and other externalities, increased collaboration among economic stakeholders, researchers, and local governments will be necessary to effectively leverage these new technologies. This can be achieved by coordinated efforts between stakeholders to improve the quality and efficiency of deliveries, while also ensuring that cities remain attractive and liveable spaces.

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Notes

1 www.haropaport.com/en
2 http://avfutures.nlc.org/jobs-and-the-economy

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Index

Note: Page numbers in *italics* indicate figures, and page numbers in **bold** indicate tables on the corresponding page.