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EDITORIAL

Port-hinterland transport and logistics: emerging trends and frontier research

Behzad Behdani[1] · Bart Wiegmans[2] · Violeta Roso[3] · Hercules Haralambides[4,5,6]

1 Introduction

Cargo carried by liner shipping has come to be known as general cargo.[1] Up to the beginning of the 1960s, such cargo was transported, in various forms of unitization (packaging), such as pallets, slings, boxes, barrels and crates, by relatively small ships, known as general cargo ships, cargo freighters, multipurpose ships, twin-deckers or multi-deckers. Cargo handling was a very labour-intensive process and ships were known to spend most of their time in port, waiting to berth, load or discharge. Congestion was a chronic problem in most ports, raising the cost of transport and hindering the growth of trade. Equally importantly, such delays in ports made trade movements erratic and unpredictable, obliging manufacturers, wholesalers and retailers to keep large stock. As a result, warehousing and carrying (capital) costs were adding up to the cost of transport, making final goods more expensive and, again, hindering international trade and economic development[2] (Haralambides 2019).

This situation started to change in the 1960s with the introduction of the 'container' and *containerization* in the trade between the United States and Europe and,

[1] This introduction leans heavily on Haralambides (2017, 2019).

[2] Cases have also been known where inefficient ports were welcomed (if not deliberately pursued) by governments, as an effective *tariff* and barrier to foreign imports.

✉ Behzad Behdani
behzad.behdani@wur.nl

1 Operations Research and Logistics, Wageningen University and Research, Hollandseweg 1, 6706 KN Wageningen, The Netherlands

2 Department of Transport and Planning, Delft University of Technology, Delft, The Netherlands

3 Division of Service Management and Logistics, Chalmers University of Technology, Gothenburg, Sweden

4 Dalian Maritime University, Dalian, China

5 Texas A&M University, College Station, USA

6 Erasmus University Rotterdam, Burg. Oudlaan 50, 3062 PA Rotterdam, The Netherlands

subsequently, in the rest of the world. Containerization is often described as a *revolution* in transport. The innovation entailed in the concept of *containerization* is credited to Malcolm Mclean, an American trucker who thought of separating the tractor from the trailer part of his trucks, standardizing (unitizing) the latter (trailer) so as to be able to be transported with its contents intact by various transport means, handled at ports by standardized cargohandling equipment (quay cranes), and stacked uniformly one on top of the other, both on ships and at terminals. This was the start of *intermodality*, as well as of mega-ships and mega-ports, inland terminals, distribution centers (dry ports) and global logistics, by and large (Van Klink and van Den Berg 1998; McCalla 1999).

However, in spite of the sustained growth of port throughput worldwide, as well as of the substantial infrastructure investments of ports and their efforts to reform and modernize, hinterland transport—representing 60% of the costs of the global maritime supply chain (Beresford et al. 2012)—has not kept pace; productivity in the maritime leg of the supply chain has not been followed by productivity in its hinterland part, apart from the introduction of double-stack trains in the US in the 1980s (DeBoer 1992), or the adoption of the dry port concept in the 2000s (Roso et al. 2009). Moreover, the *gigantism* in container shipping[3] is straining port infrastructure and cargohandling capacity, causing significant *diseconomies of scale*, which propagate throughout the supply chain, given that increases in port throughput generate almost proportional increases in hinterland flows, and functional seaport hinterland access is essential for the efficiency of the whole intermodal transportation chain. For many seaports, the weakest link in their transportation chains is hinterland access, due to congested roads and inadequate or non-existent rail connections, causing delays and increases in transport costs. The Transport Research Board (1993), as early as the 1990s, identified those infrastructure, land use, environmental and institutional impediments that reduce the efficiency of hinterland transport. To add to this, the quality of hinterland transport and inland access of ports depend on the behaviour of a large number of stakeholders involved in the seaport-transport system (de Langen and Chouly 2004; Paixão and Bernard Marlow 2003).

A reversal of trends can recently be seen. From the earlier days when ports were obliged to move downstream to find space, ports now look back at their hinterlands to find the additional space they require. Inland intermodal terminals (or dry ports) are thus mushrooming, connected to seaports by rail, road or inland waterways (Haralambides and Gujar 2011, 2012). As such, inland intermodal terminals are usually developed close to railway and motorway junctions to facilitate the transfer of containers between modes of transport, favoring, to the extent possible, the more environmentally friendly transport modes, such as rail and inland waterways (Rodrigue et al. 2016; Haralambides 2020).

A digression might be in order here. Despite various policies proposing and encouraging an increasing use of rail and intermodal solutions, especially in the European Union, the modal share of rail transport has been decreasing, mostly

[3] At the time of writing, the biggest containership was the MSC Gulsun, capable of carrying up to 23,756 twenty-foot equivalent units (TEU).

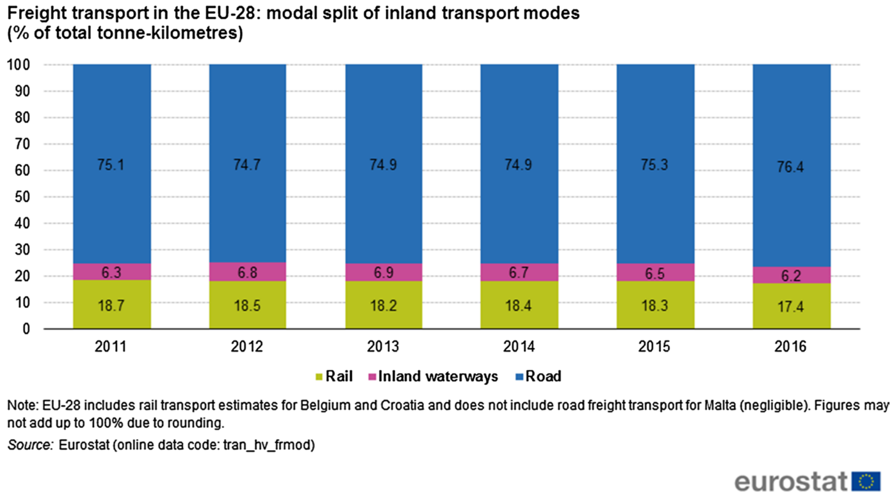

Fig. 1 Freight Transport in the EU-28: modal split of inland transport modes (EEA 2009)

due to the removal of trade barriers and the liberalization of markets, which have resulted in an increased market share of road transport, representing 76.4% of inland freight transport in 2016 (EEA 2009) (Fig. 1). In the European Union, a change in the geographic orientation of trade and economic activity from the west to the east has also contributed to this situation, since the new markets are not well connected by rail, so therefore road prevails due to its flexibility (EEA 2009).

Containerization and intermodality have extended the hinterland of seaports and redefined seaport competition in a way that seaports now have to strive for a position in intermodal corridors (Notteboom 1997, 2006; Haralambides 2019).

In all cases, the role of the Port Authority (PA)—the autonomous body which manages the seaport—is crucial. PAs are assuming an increasingly enterprising role as 'stakeholder managers', extending their 'gates' to the hinterland, as far out as possible, to widen their catchment areas. To do this, the 'smart port authority 4.0' needs to smooth out supply chain bottlenecks among ships, terminals, customs authorities, and hinterland transport, storage and distribution. In its supply chain manager role, the seaport of today understands that it is now supply chains, not ports, that compete for custom (Haralambides 2020). Together with intra-port efficiency, therefore, the focus of port management is now also drawn to hinterland access via more active involvement in innovative logistics. Often, the objective of such efforts entails a shift of container flows from road to *Intermodal Freight Transport* (IFT) networks (both rail and inland waterways).

Such a role for PAs requires modern management practices and the transformation of the PA from a government dependency to an entity operating under increasingly commercial terms. Often, 'stakeholder management' is an extremely frustrating exercise in view of conflicting interests, particularly when such 'stakeholders' sit in the governing or supervising boards of port authorities.

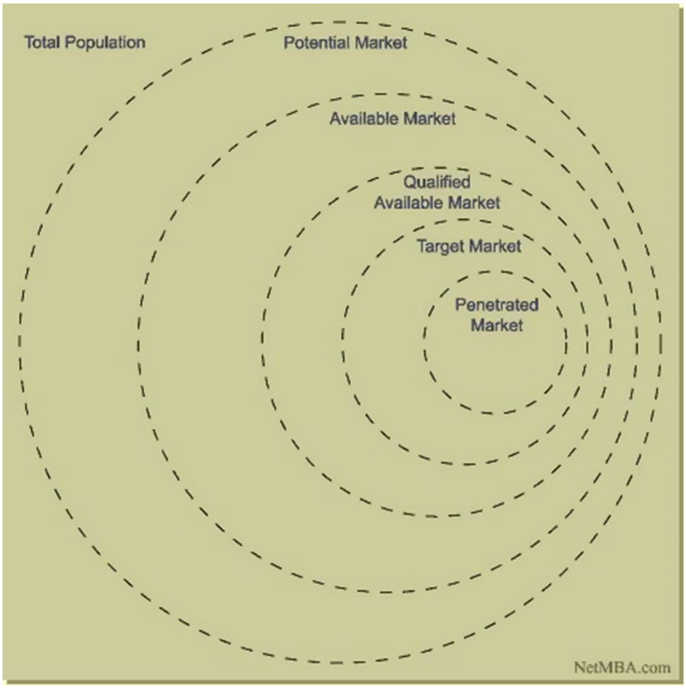

Fig. 2 Market definition. *Source* NetMBA.com

A port's hinterland is no longer static but dynamic. Thirty years ago, when port traffic was captive, one's students could easily calculate the optimum size of a port, based on the country's trade, population and growth data. Today, with expanding hinterlands and competition among ports, researchers would have to take a guess (i.e., forecast). The problem, however, is that someone will have to pay for this guess and this can no longer be the taxpayer. Rather, it has to be one whose role is to assume risk and be rewarded or punished for it; i.e. the private sector (Haralambides 2019).

From a *competition economics* and *law* point of view, the concept of 'hinterland', which is of interest, is expressed by the *relevant geographic market* (Haralambides 2017). A market has a geographical attribute which is of relevance in determining concentration and competition. For instance, the market of the city where the port is located is fairly *captive*. But as the port tries to extend its hinterland towards the region, the country or the continent, the market becomes just a *potentially targetable* market, with more players and thus more competition (Fig. 2). To give another example: The Shanghai-Rotterdam *port-to-port* market may be highly concentrated, with just a handful of carriers offering services, but if one were to consider that, actually, the market is the *door-to-door* importation of bicycles made in Wuhan, China to Paris, France, then the market is highly competitive with many players offering services, using not only those two ports but many others, at both ends of the trade. Simply put, if the market is

Table 1 Overview of article searching terms

Key term	Number of articles found
intermodal	88
hinterland	72
"intermodal freight transport"	12
"inland shipping"	2
"inland waterways"	8
"rail transport"	5
"road transport"	9
Total	196

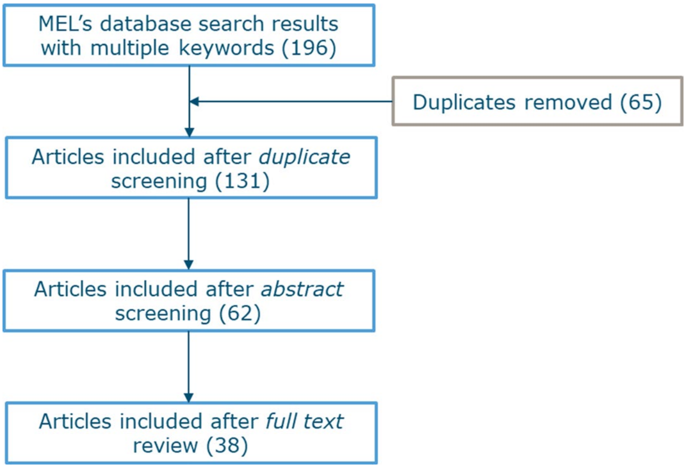

Fig. 3 Approach for paper selection

port-to-port, it could indeed be concentrated; if however the market is *door-to-door*, including a miscellany of *add-on* logistics services, it could well be considered as not concentrated at all (Haralambides 2017).

2 The contribution of MEL to port-hinterland logistics and intermodal transport

This section presents an overview of papers published in MEL on port-hinterland transportation. For this review, a structured and systematic approach in four phases was carried out. In the first phase, a pool of relevant papers was extracted from the MEL database in Scopus. The search was performed primarily using the more generic terms of "intermodal", "hinterland", and "intermodal freight transport" in the title, abstract, and keywords of published papers. The search was further extended with more specific key terms such as "inland shipping", "inland

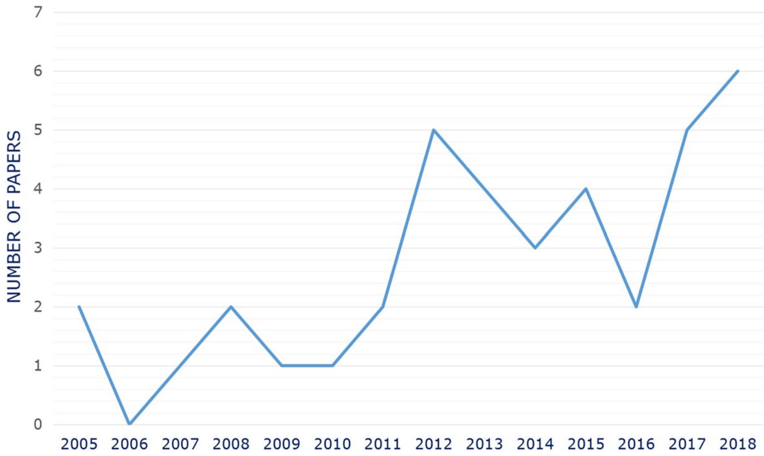

Fig. 4 Distribution of MEL articles on port-hinterland logistics and intermodal freight transport over time

waterways", "rail transport", and "road transport". The search was limited to those articles published by the end of 2018. The number of articles with each search term is shown in Table 1.

Our search resulted in 196 articles (Fig. 3). In the second phase, articles were screened to identify duplicates. This narrowed the results to 131. These articles were reviewed in two phases to find the relevant ones. Firstly, the abstracts were reviewed, filtering 62 articles for the second phase, in which the articles were read in full, narrowing the list to 38 relevant articles. Those were the articles that either discuss only port-hinterland and intermodal freight transport, or articles in which a considerable part focuses on these topics. Papers with a focus on terminal operations, which only marginallydiscuss hinterland transport, or papers on port competitiveness where land transport or hinterland accessibility are just two among several factors were excluded from our analysis.

As Fig. 4 shows, the number of MEL articles on port-hinterland logistics and intermodal freight transport has been increasing steadily from 2005 to 2018. Selected papers were categorised into three groups, based on their main research area:

(i) Economic studies, focusing primarily on market mechanisms, market efficiency, as well as demand or cost analysis;
(ii) Operational studies, addressing the logistics and operational processes in hinterland transport;
(iii) Organizational/regulatory studies, focused on 'stakeholder management' and the relationship between stakeholders, as well as on analysing the regulatory and policy interventions. This category also includes the innovative business models for port-hinterland logistics.

Table 2 Overview of articles, their aim and findings

Source	Title	Aim of research	Methodology	Findings
Economic aspects				
Wang et al. (2018a)	Modelling ocean, rail, and truck transportation flows to support policy analysis	To develop a multi-model freight transportation to estimate the international and domestic freight flows across ocean, rail, and truck modes	Mathematical modelling	The paper integrates a multimodal user equilibrium model of freight flows with a system-optimal representation of the rail network. It can be used to study the impacts of infrastructural changes, or imposing new user fees (e.g., congestion pricing) and changes in operating policies. The model is illustrated by two case studies: (1) a disruption of the seaports of Los Angeles and Long Beach; and (2) implementation of new port user fees in California.
Wang et al. (2018b)	The effect of distance on cargo flows: a case study of Chinese imports and their hinterland destinations	To analyse the relationship between cargo flows and distances for 63 Chinese ports and their hinterlands	Spatial Concentration Analysis; Distance–decay analysis	This paper discusses a geographic perspective (spatial concentration/decentralization patterns) of port hinterlands in China. A spatial concentration analysis of the top 63 Chinese ports, to study the port-hinterland cargo flows, resulted in some insightful results: approximately 28% of the 63 ports distribute nearly all imported cargo to local provinces, and 65% of the ports deliver 90% of imported cargo to local provinces. The authors show that hinterland cargo volumes are structured according to the Gompertz growth curve. With distance, initially, the cumulative hinterland cargo volume of a port increases in an accelerated growth phase, reaches an inflection point at a certain distance, enters a decelerated growth phase, and finally reaches saturation.
Button et al. (2017)	Economic implications for Adriatic seaport regions of further opening of the Northern Sea Route	To study the geographical and economic implications of Northern Sea Routes (NSRs) between Asia and Europe for the Adriatic region	Mathematical modelling and simulation	This paper studies the possible geographical and economic implications if the use of the Northern Sea Routes (NSRs) between Asia and Europe becomes viable. The availability of the NSR changes the comparative attractiveness of ports, their absolute costs, and accordingly the sizes of their hinterlands. The attractiveness of the southern ports of the Adriatic could decline by as much as nine per cent. In contrast, the importance of the inland transport systems serving the North Atlantic ports is likely to grow, and intermodal hinterland networks become more important.

Table 2 (continued)

Source	Title	Aim of research	Methodology	Findings
Garcia-Alonso et al. (2017)	Port competition through hinterland accessibility: the case of Spain	To study the relation between the market share of ports in contestable hinterlands and the use of rail shuttles to key inland terminals	Analysis of Geographic Information System (GIS) data and traffic flows	Using an analysis of competition between three major ports in Spain (i.e., Barcelona, Bilbao and Valencia) in the period of 2008–2013, authors find that rail transport is not a necessary condition for the growth of hinterlands in this case (some ports like Valencia could capture a good share of distant hinterlands even with a low use of rail). Instead, hinterland distance is still the most important variable for inland freight transport and port choice.
Lu and Yan (2015)	The break-even distance of road and inland waterway freight transportation systems	To determine the break-even distance of road and inland waterway transportation systems	Mathematical modelling	A model considering the internal and external costs of road and inland waterway transportation systems is presented to determine the break-even distance. The model was applied to a case in the Yangtze River Delta in China. Handling rates have a significant effect on the breakeven distance. Also, the policy of internalisation of externalities clearly decreases the break-even distance and reduces the market share of road transportation.
Thill and Venkitasubramanian (2015)	Multi-layered hinterland classification of Indian ports of containerized cargoes using GIS visualization and decision tree analysis	To analyse the spatial structure of the hinterlands of major Indian ports and study the extent of inter-port competition among them	GIS-based origin-destination (OD) visualizations, Decision Tree Modelling	The results of this study make explicit comparisons of market share of each of the 11 major Indian ports at a state and regional level that could assist strategic planning of logistical facilities and infrastructure. The results also demonstrate the utility of this data mining method to understand the dynamism of hinterlands that have long been regarded as static spatial objects, by introducing commodity and shipment value dimensions.
Iannone (2012)	A model optimizing the port-hinterland logistics of containers: The case of the Campania region in Southern Italy	To investigate the economics and strategic planning of port-hinterland container logistics of the Campanian seaport cluster (South Italy)	Mathematical modelling; case study	This article presents a multimodal and multi-commodity optimization model, called the 'inter-port model', for the economic analysis and strategic planning of port-hinterland container logistics systems. The model is next employed to study the inland distribution of import/export containers from/to the Campanian seaports of Naples and Salerno.

Table 2 (continued)

Source	Title	Aim of research	Methodology	Findings
Padilha and Ng (2012)	The spatial evolution of dry ports in developing economies: The Brazilian experience	To analyse how port development can influence the spatial evolution of dry ports in developing economies	Semi-structured in-depth interviews	The findings of this article show that the spatial pattern of port development in the literature—mainly based on experiences from developed economies—might vary significantly in the context of developing countries. In the latter case institutional barriers are especially critical factors. As a result, some key stages of port development might be late, poorly developed, or even skipped altogether. For instance, intermodality has been poorly developed and there has been almost no use of rail for container transportation. Also, high-capacity road corridors have been insufficient.
Operational aspects				
Wiegmans et al. (2018)	Communication between deep sea container terminals and hinterland stakeholders: information needs and the relevance of information exchange	To study the information needs of container terminals and hinterland actors and highlight the importance of different information types for different stakeholders	Gate survey, interviews and questionnaires	The information needs of parties in the hinterland transport are divided into three main categories: (1) information about containers, (2) information about transport means and (3) information about deep sea terminals. The importance of each information type for each hinterland party is discussed.
Tokcaer and Özpeynirci (2018)	A bi-objective multimodal transportation planning problem with an application to a petrochemical ethylene manufacturer	To present a model to support multimodal transportation planning by a shipper	Mathematical modelling	This paper presents a mathematical model for multimodal transportation planning, which includes the selection of transportation mode(s) and the assignment of demand to them according to capacities. The model is illustrated using a case of a Turkish petrochemical ethylene manufacturer.

Table 2 (continued)

Source	Title	Aim of research	Methodology	Findings
Tran et al. (2017)	Container shipping route design incorporating the costs of shipping, inland/feeder transport, inventory and CO_2 emissions	Presenting a model to design the optimal shipping service network considering end-to-end service (integrating both maritime and inland factors)	Mathematical modelling	The maritime network is only a part of a bigger system. Optimising shipping routes only may not guarantee the optimisation of the whole network. The computational results of a case between the United States and European countries reveal that inland/feeder transport costs are the highest among supply chain costs and they are influenced by the selection of ports. The greater the number of port calls, the lower these costs are. High inland/feeder transport costs favour ports close to final markets (in attracting shipping calls), as well as route patterns with multi-port calls.
Tong and Nachtmann (2017)	Cargo prioritization and terminal allocation problem for inland waterway disruptions	To present a decision support tool to manage disruptions in inland waterways	Mathematical modelling	This article presents a mathematical modelling framework—called the cargo prioritization and terminal allocation problem (CPTAP)—to handle the potential impacts of inland waterway disruptions. CPTAP helps in minimizing total value loss by optimally prioritizing disrupted barges considering different prioritization factors such as commodity type, cargo value, terminal capacity and barge draft.
Odchimar and Hanaoka (2017)	Intermodal freight network incorporating hub-and-spoke and direct calls for the archipelagic Philippines	To present a freight-network model that integrates intermodal transport in a hub-and-spoke system	Mathematical modelling	The presented model helps in locating hub ports where intermodal road-RoRo and container transport could tranship and be used complementarily. It is shown that considerable savings in total network costs could be realized in a mixed network of hub-and-spoke (HS) and point-to-point (PTP) topology, compared to a purely PTP one.
Moon and Hong (2016)	Repositioning of empty containers using both standard and foldable containers	To present a decision model for the repositioning of standard and foldable containers at minimum cost	Mathematical modelling	This is a model to minimize the total cost of transportation, inventory, handling, folding and unfolding processes, container leasing, and installation of facilities for folding and unfolding containers.

Table 2 (continued)

Source	Title	Aim of research	Methodology	Findings
Hekkenberg (2016)	Optimization of the dimensions of dry bulk ships: The case of the river Rhine	To study the optimal ship dimensions for dry bulk ships that operate on the river Rhine	Mathematical modelling	This paper presents methods to find the optimal ship dimensions from two different perspectives: (1) the minimization of ship-related costs in determining the breakeven freight rate; (2) the minimization of total logistics costs. The results are summarized in a flow chart that allows the identification of favourable ship dimensions as a function of transport distance, water depth in ports and annual transport demand. One finding in the article for the case of bulk barges in the Rhine is that the length of dry bulk ships with dimensions that minimize the required freight rate and total logistics costs usually does not exceed the maximum allowed length of existing ships, that is, 135 m. So, it is not necessary to increase the regulatory upper limit of ship length on the Rhine. However, the beam of optimal ships is typically wider than the common widths of 11.45 and 15 m, while optimal ships have a draft that matches or slightly exceeds the maximum draft at normal water levels on the route.
Van Riessen et al. (2015)	Impact and relevance of transit disturbances on planning in intermodal container networks using disturbance cost analysis	To study the effects of disturbances in the operational planning of container transportation in an intermodal network	Mathematical modelling	A Linear Container Allocation model with Time-restrictions (LCAT) is proposed to find cost-effective solutions to the container transportation planning problem, and assess the effect of disturbances on operational planning. The model is applied to the European Gateway Services (EGS) network.
Özpeynirci et al. (2014)	Multimodal freight transportation with ship chartering	To present a model for supporting the optimal ship chartering and multimodal transportation decisions	Mathematical modelling	A mathematical model for multimodal transportation is discussed and applied to a real-life case. The developed model considers multimodal transportation, ship alternatives, ports and possible routes between subsets of ports.

Table 2 (continued)

Source	Title	Aim of research	Methodology	Findings
Vojdani et al. (2013)	Optimizing empty container logistics based on a collaborative network approach	To demonstrate the potential for cost savings through the use of container pooling in collaborative empty container management	Mathematical modelling	This article presents a mathematical model to study the cost savings of container pooling. Calculations based on maritime network scenarios and generated order data demonstrate significant economic benefits (up to 10% cost reduction) for shipping lines and maritime stakeholders.
Olivo et al. (2013)	An optimization model for the inland repositioning of empty containers	To study the inland repositioning of empty containers	Mathematical modelling	The paper presents a mathematical model for inland container repositioning considering the inventory and transportation aspects, as well as the substitutions of company-owned and leased containers. The proposed model can determine when and where containers should be hired on and hired off, taking into account clauses imposed by rental contracts. It also determines the flows of empty containers shipped to and from ports in a cost-optimal way.
Ambrosino et al. (2013)	A mathematical model to evaluate different train loading and stacking policies in a container terminal	To evaluate the impact of different storage strategies and loading plans for trains on import containers in maritime terminals	Mathematical modelling	Nine different policies, obtained from the various combinations of train loading policies (sequential, non-sequential and partially sequential) and stacking ones (random; based on container weight; and based both on container weight and on its commercial priority) have been tested and evaluated using a mixed integer linear programming model. The analysis of the results shows that the preferable storage and loading policies can be different in different cases. The best policy depends on the specific terminal KPI and its operative context (in terms of layout, handling resources, procedures, etc.).

Table 2 (continued)

Source	Title	Aim of research	Methodology	Findings
Dang et al. (2013)	Replenishment policies for empty containers in an inland multi-depot system	To present a model to support shipping companies in allocating empty containers between multi-depots, and implement an appropriate leasing policy	Mathematical modelling	This article considers the coordination of positioning empty containers from overseas ports to inland depots. Container leasing options are also discussed to define the best integrated policy that minimizes the expected total costs (which include the inventory holding, overseas positioning, inland positioning and leasing costs).
Shintani et al. (2012)	The effect of foldable containers on the costs of container fleet management in liner shipping networks	To study the problem of container fleet management and the potential of foldable containers (with focus on the cost of empty repositioning)	Mathematical modelling	An integer programming model is developed in this article to study the potential savings of using foldable containers in a liner shipping network. With numerical studies, authors show that using foldable containers, especially when there is a strong trade imbalance, can generate substantial savings in container fleet management costs. Yet, the exploitation costs of a foldable container play a major role in determining the feasibility of these savings. A mixed container fleet consisting of both normal and foldable container types might be a viable option.

Table 2 (continued)

Source	Title	Aim of research	Methodology	Findings
Zhao and Goodchild (2011)	Truck travel time reliability and prediction in a port drayage network	To explore the travel time reliability of a port drayage network and evaluate the predictability of drayage truck travel time	Data analytics; case study	This research addresses the question of the confidence by which one can predict truck arrival times at terminal gates. Authors use *standard deviation* and *coefficient of variation* for "trip reliability analysis" and "network reliability analysis" across different OD pairs, and throughout different times of day. From the results of a case study at the Ports of Los Angeles and Long Beach, authors concluded that *time of day* has a significant impact on travel time reliability, whereas *trip length* has a lower impact on reliability. The relationship between routing choice and route attributes is also examined. Finally, a simple method is proposed to predict the confidence interval of truck travel time between the given OD pair. This method is further validated and applied to an entire drayage network to evaluate how truck travel time varies across the temporal and spatial attributes of a network.
Song and Dong (2011)	Flow balancing-based empty container repositioning in typical shipping service routes	To study and model the empty container repositioning problem for general service routes based on container flow balancing	Mathematical modelling	This article discusses the empty container repositioning problem in shipping services based on container flow balancing Two types of flow balancing policies are formulated and analysed: point-to-point repositioning policy (P2P) and a coordinated repositioning policy (CRP). The performance of the two policies and their sensitivity to route structure and trade demand pattern (for example, degree of trade imbalance) is also investigated.
Parola and Sciomachen (2009)	Modal split evaluation of a maritime container terminal	To analyse the performance of a maritime container terminal and its intermodal connections to the hinterland	Discrete-event simulation; case study	This paper presents a simulation study aiming to improve the modal split of port-hinterland transport (focusing on road and rail connections). Different scenarios for improving the performance of rail connections (instead of increasing investments in rail infrastructure) are presented and studied using the simulation model. The model is applied in the port of Genoa, 'Voltri Terminal Europa' (VTE).

Table 2 (continued)

Source	Title	Aim of research	Methodology	Findings
Rahimi et al. (2008)	An inland port location-allocation model for a regional intermodal goods movement system	To present a model for analysing the location of inland ports in a hinterland network	Mathematical modelling (location-allocation models)	The paper presents a mathematical model to find the optimal location of "satellite inland ports". The presented approach is illustrated using a case of an inland port system in southern California. The results imply reductions in vehicle-miles travelled, which further contributes to reducing externalities such as congestion and air pollution.
Vernimmen et al. (2007)	Schedule unreliability in liner shipping: Origins and consequences for the hinterland supply chain	To investigate the origins of liner schedule unreliability and its impact on the actors, especially of the hinterland supply chain	Mathematical modelling; case study	This paper discusses the impact of liner shipping schedule integrity on chain actors, especially on shippers/consignees. The impacts are discussed through a case study of a South African manufacturer who sources spare parts globally. The improvement in schedule reliability is shown to have significant cost savings for the company.
Olivo et al. (2005)	An operational model for empty container management	To present a model to support decisions regarding the management of empty containers	Mathematical programming; case study	This paper presents a mathematical model for the operational management of empty containers in a deterministic dynamic multimodal network. The model uses the hour as the time-period of the multi-period network planning, which helps the real-time management of heterogeneous fleets (i.e., different sizes) of empty containers. The application of the model to a case of Mediterranean basin network with ten ports and more than thirty demand areas illustrates the value ofthe model in managing empty containers in real-time scenarios.
Organizational/regulatory aspects				
Jeevan et al. (2018)	Determining the influential factors of dry port operations: worldwide experiences and empirical evidence from Malaysia	To study the influential factors in dry port operations	Online questionnaire survey and regression analysis	The paper identifies five categories of influencing factors (i.e., hinterland condition, service features, capacity, government policy, and information Systems) on dry port operations and conducts an empirical study, through a web-based survey of Malaysian dry port stakeholders, to analyse the importance of those factors. Analysis of results shows that an information system for collaboration and coordination, such as a port community system, is the most influential factor for Malaysian dry ports' operations.

Table 2 (continued)

Source	Title	Aim of research	Methodology	Findings
Parola and Lam (2018)	An empirical investigation of logistics infrastructure projects in emerging economies	To investigate the impact of financial/technical complexity of logistics infrastructure projects on the implementation of dependence-reducing strategies in public–private partnerships (PPPs)	Resource Dependence Theory; multivariate multiple regression analysis	This paper presents an empirical investigation on a sample of 1300 PPP logistics infrastructures in order to assess the impact of financial and technical complexity of PPP projects on the pursuit of (multiple) dependence-reducing strategies. The results show that large financial scale and technical complexity stimulate investors to build wide PPP consortia and to select partners with experience in PPP logistics infrastructure ventures, as well as familiarity with the cultural aspects of the local area. This is expected to moderate the risk and uncertainties deriving from PPP project complexity. A great financial scale of PPP logistics infrastructures also stimulates investors to select partners with a homogeneous endowment of resources and organizational capabilities, in order to reduce managerial and organizational difficulties. Also, a higher technical complexity drives private investors to joint cross-border PPP projects in a cultural area analogous to that of their own countries. In other words, cultural fit in business practices, work ethic and principles and language help in the effective exchange knowledge with local institutions and private organizations, and handle the technical complexity.

Table 2 (continued)

Source	Title	Aim of research	Methodology	Findings
Van Den Berg and De Langen (2015)	Assessing the intermodal value proposition of shipping lines: Attitudes of shippers and forwarders	To study the assessment of the value propositions of shipping lines by shippers and forwarders	Survey	Shippers and forwarders differ in what they consider as important in the offer of shipping lines. However, both are mainly cost driven. Both shippers and forwarders have a rather limited interest in sustainability. Forwarders attribute the lowest importance to sustainable operations. Shippers and forwarders also differ in their bookings. Forwarders mainly book on a port-to-port basis and they have a relatively small share in door-to-door bookings. In contrast, shippers have a larger share of door-to-door bookings. Their findings suggest that providing door-to-door bookings is not (any longer) a source of differentiation for shipping lines. Door-to-door transport is not less price sensitive than port-to-port transport. The findings indicate that price is most important to customers, regardless of the type of booking (door-to-door or port-to-port). Both forwarders and shippers are interested in an Inland Terminals (ILT)-centred proposition—shipping lines do not offer the 'last mile' but bring containers to ILT. Especially, customers with a large share of door-to-door bookings are more interested in such a service.
Haezendonck et al. (2014)	A new governance perspective on port-hinterland relationships: The Port Hinterland Impact (PHI) matrix	To develop a tool for governance-based analysis of contractual relationships in port-hinterland	Interview and data analysis	The paper introduces the PHI matrix as an analytical tool, providing insights into the hinterland impact of a port and consequently supports 'optimal' contracting with hinterland actors. The PHI matrix has two dimensions: first, "a port's geographic reach" (how much of the port traffic travels a specific distance, for example 100 or more kilometres, from and into the hinterland) and second, the "difficulty of port substitution/dedicatedness of logistic chain" (how difficult is port substitution or how dedicated is the logistics chain involved). The framework is applied to two cases (port of Zeebrugge and port of Antwerp).

Table 2 (continued)

Source	Title	Aim of research	Methodology	Findings
Min and Jun (2014)	Public-private partnerships for the development of port hinterlands and their ramifications for global supply chain management	To identify the challenges, opportunities and policies associated with port hinterland development through public–private partnerships (PPP)	Case study	The article develops a conceptual framework for systematically managing PPPs in hinterland development projects and introduces best practices through the illustrative case study of a hinterland project undertaken by the Port of Busan. Some of the main findings of this research include: The goals of hinterland development should be consistent with the specific roles of ports and their hinterlands. To boost PPP opportunities for hinterland development, the 'right' combinations of incentives, which are more inclusive than exclusive, should be identified.
Veenstra et al. (2012)	The extended gate concept for container terminals: Expanding the notion of dry ports	To study and to position the extended gate concept as a business network innovation	Conceptual and case study	The extended gate concept is an innovative business model in which sea terminals and inland terminals are involved in a partial integration of their processes at the transport level. The central idea is to extend the delivery point, from the perspective of the shipper/receiver, from the seaport terminal, along a corridor to an inland multimodal terminal.

Table 2 (continued)

Source	Title	Aim of research	Methodology	Findings
Beresford et al. (2012)	A study of dry port development in China	To investigate the existing dry port developments in China and how the existing institutional and regulatory framework has influenced dry port development in China	Case study	This article studies how the existing institutional and regulatory framework has influenced dry port development in China. The lack of a unified top-level institutional coordination body is found as a challenge to this development. Three ministries operate independently with different roles in planning, operating and regulating inland intermodal transport systems, and this has hindered dry port development. Second, local government has considerable autonomy in interpreting Central government policy according to local needs. Third, a comprehensive regulatory framework for dry port development is still absent. Authors also found that different dry ports in China are at different stages of development. Under a loose institutional structure, government intervention has become necessary to solve the financial problems and leverage public relations. Also, a systematic policy framework and a standard dry port definition are needed.
Roso and Lumsden (2010)	A review of dry ports	To give an overview of the existing research on the dry port concept as well as of the world's existing dry ports	Review	This article reviews the existing literature on dry ports. It also reviews the existing dry ports around the world. Accordingly, the paper helps to clarify the concept and understand the potential discrepancies between theory and practice. The paper also discusses the main advantages of dry ports, including improved customer service and creation of new jobs in the area, as well as supporting regional growth, particularly in the case of landlocked countries.

Table 2 (continued)

Source	Title	Aim of research	Methodology	Findings
Van Der Horst and De Langen (2008)	Coordination in hinterland transport chains: A major challenge for the seaport community	To analyse the coordination schemes and problems in the hinterland chains of seaports	Institutional economics analysis; case study; expert interviews	Some main findings of the paper include: Coordination in the hinterland is important, as hinterland transport costs are generally higher than maritime transport costs. Most bottlenecks of the door-to-door container transport chain occur in the hinterland network (e.g., congestion, insufficient infrastructure, etc.). The main areas of hinterland coordination requirements are identified and discussed. These include container barging, trucking, and container rail transport systems. Examples include the limited exchange of cargo and transport capacity, unused and overused rail and road infrastructure, and limited information exchange with customs and inspection authorities. Based on insights from institutional economics, a framework for the analysis of coordination problems and the evaluation of mechanisms to enhance coordination is presented. This framework features four key mechanisms to enhance coordination: the introduction of incentives, the creation of inter-firm alliances, changing the scope of an organization (e.g., vertical integration), and the undertaking of collective action. For each coordination problem, arrangements to enhance coordination are identified and classified into one of the four mechanisms of coordination. The problems and solutions are further elaborated in the case of the Port of Rotterdam.
Islam et al. (2005)	Towards supply chain integration through multimodal transport in developing economies: The case of Bangladesh	To present a normative model for supply chain integration in developing countries and the roles of multimodal freight transport	Case study	The paper presents a holistic model of a multimodal transport system aiming at supply chain integration. Using a case study in Bangladesh, authors discuss the barriers to supply chain integration in developing economies within the scope of multimodal transport.

The details of the aim and contribution of the articles in these three groups are presented in Table 2. Although the categorization in Table 2 is not intended to be definitive (since some articles may discuss more than one topic), the main topic has been used in the categorization of Table 2. Thus, the table provides a general overview of problems addressed by different researchers and their key findings. For operational and economic aspects, the dominant methodology is mathematical modelling. For organizational aspects, the survey and case study methods are the most widely used methods. It is interesting to observe that as many as 85 percent of the papers discuss a case—as the main research method, or to illustrate their models or frameworks—which demonstrates the highly practical relevance of the findings in these articles.

3 Contents of this special issue

This special issue brings together five papers representing cutting edge research currently pursued in the area of *port-hinterland transportation*. In the first paper (*The geography of container port choice: modelling impacts of changes in hinterland variables on port choice*), Mueller, Wiegmans and van Duin study the position of port hinterlands in the modelling of port choice. Their model discusses how containerized imports could be affected by changes in the hinterland strategies of ports and hinterland corridors, as well as by changes in inland port operations. They further model the impact of fuel prices on port hinterlands. They find that although a rise in fuel prices might reduce road transport, this is influencing the competitive position of ports at a European level.

The role of the hinterland in port choice is also studied by Caballe-Valls, de Langen, Garcia-Alonso, and Vallejo-Pinto (*Understanding port choice determinants and port hinterlands; findings from an empirical analysis of Spain*). Based on detailed Spanish customs data, the authors show that intermodal connectivity is a determinant of the market share of a port in a certain hinterland region. Additionally, the authors show that, in the case of Spanish ports, there are no clear 'boundaries' between the hinterlands of different ports, which thus have market shares in 'contestable hinterlands'. Finally, it is also shown that hinterlands may actually differ, depending on overseas destination.

In their paper, *The impact of foldable containers on cost savings in empty container relocation by trucks in the hinterland of seaports*, Shintani, Konings, Nishimura, and Imai focus on the empty container relocation problem in hinterland transport. Empty container re-positioning is an important operational issue in maritime logistics. Foldable containers may present a potential solution, since when an empty container is folded, it needs less space on transport means. The authors present a model to address the integrated problem of truck routing and empty container relocation by using foldable containers.

In *Involvement of port authorities in inland logistics markets: the cases of Rotterdam, Le Havre, and Marseille*, Magnan and van der Horst discuss an important organizational and governance aspect of port-hinterland logistics, i.e., the role of port authorities in the development of inland logistics markets. The authors discuss the typology of different roles, actions and instruments that port authorities can adopt within inland logistics markets. They further study three cases: Port of Rotterdam (the Netherlands), Le Havre (France) and Marseille-Fos (France). The case studies rely on in-depth interviews with port authorities and public administrations and illustrate the different paths followed by the three port authorities. In Rotterdam, there has been a shift from a conservator to a facilitator model and later to an entrepreneurial role. However, the port authority has recently withdrawn from its entrepreneurial role, presently functioning more like a facilitator. The port authorities of Le Havre and Marseille-Fos mix the conservator and facilitator models.[4]

In the last paper of this issue, *a framework for modelling and analysing coordination challenges in hinterland transport systems*, Gumuskaya, van Jaarsveld, Dijkman, Grefen, and Veenstra focus on an important organizational issue in port-hinterland logistics. They present a framework for exploring the coordination challenges in hinterland transport within three layers of transportation processes: *contracting*, *planning* and *physical* processes. The framework can help in formalizing coordination models and in gaining insights into the dynamics of coordination challenges. Their effort is illustrated through a case study of barge congestion in the Port of Rotterdam.

4 Further research and agenda for action

Based on the contributions in this special issue and on our own research overview, we have, subjectively of course, identified the following areas for further research on maritime transport, ports and hinterlands: *coping with increasing volumes*; *synchromodality*; *sustainability of intermodal freight transport*; *the value of information in intermodal transport*; *formalization of relations among stakeholders*; *intermodal freight transport policy making*; and *cooperation versus control*.

Gigantism in container shipping (Haralambides 2019) creates challenges both for seaports *and* their hinterland. In a number of cases, capacities of inland modes and inland terminals have not kept pace with the growth in ocean transportation. These shortages manifest themselves in congestion and also in sustainability issues (UNCTAD 2017). In terms of further research, this leads to capacity optimization efforts, performance modelling, and also research into system breakthroughs in order to reduce emissions and the environmental footprint of the transport system.

[4] In terms of position and activities, a port authority can take different functional roles (De Langen 2006; Verhoeven 2010). The landlord function aims at maintenance and development of the port estate, as well as the provision of infrastructure. The regulator function is generally about controlling and policing functions (for example in terms of safety and security of ships and cargo, or port sustainability and labor regulations). The operator function aims at providing port services, including the physical transfer of cargo between sea and land or the provision of technical services (such as fleet maintenance). A port authority can also function as community manager or cluster manager by facilitating interactions, e.g., by investing in IT communication platforms. Finally, entrepreneurial function aims at fostering innovation by direct investment or supporting innovative companies that provide the logistics services at the port or its hinterland.

Another important issue for further research is *synchromodality*. Synchromodality looks into the (integrated) combination of hinterland transport modes (rail, IWT, road). The concept of synchromodality especially attempts to integrate the planning of the different modes, and it therefore calls for the development of planning models optimizing hinterland transport (Behdani et al. 2016). Also, from an organizational point of view, we need some new and innovative contract types for synchromodality, both between customers and transport operators *and* between transport operators themselves, if the latter aim to share capacity. From an economics point of view, synchromodal pricing and the modelling of synchromodal demand are some of the areas calling for further research.

Sustainability efforts of existing intermodal modes is another research challenge. Road freight transport quickly improves its environmental performance while intermodal freight transport clearly lags behind. Efforts are needed in the development of new and cleaner technologies for intermodal freight transport. The effects of such technologies need to be studied in a way that should encourage the shift to a more sustainable freight transport system.

Efficiency improvements are often attributed to the increasing use of information in freight transport chains (e.g. Blockchain). We feel that further research is needed into the role, effects and impacts of the increasing use of *information* for, so far, the actual business cases of such efficiency improvements are missing.

An interesting issue for further research is the *formalization* of relations between stakeholders (e.g. between maritime terminals and transport operators) in freight transport chains. A notable example is the handling of barges by deep-sea terminals. The latter provide a service to the barge operator, being paid, however, by a freight forwarder or a logistics service provider. Because of this indirect relation (which is not formalized by a contact between barge and terminal operator), barges are often given lower priority compared to ocean shipping. More organizational research is needed into efficient solutions that can change this type of relationships, making them more formal. Modelling might be able to measure the efficiency impacts on freight transport chains.

Revisiting *intermodal transport policy* is another practical as well as academic area. In the last 30 years, this policy has had no effect and the market share of road transport increased from 75.1 in 2011 to 76.4% in 2016 (EEA 2009). Further research is needed into policy options that are able to increase the market share of intermodal freight transport versus single-mode road transport.

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