# Towards Efficient Multimodal Hinterland Networks

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**Abstract** Terminal operator ECT in the port of Rotterdam sought to establish a multidisciplinary research group that would support the development of a strong multimodal hinterland network concept. This was the start of the ULTIMATE project. ULTIMATE aimed to support the development "towards efficient multimodal hinterland networks". The Ultimate research agenda consisted of four elements: (1) The operational consequences of integrating transport and cargo handling activities for supply chains. This has resulted in efficient container stacking and barge routing algorithms. (2) Incorporating new business models in the design of hinterland networks. This delivered new insights in the role of information and pricing in hinterland networks. (3) The legal consequences of mixing transport and storage activities by container terminals. The contribution of this element is a more fundamental understanding of the importance of legal concepts in multimodal transport for different actors. (4) The role and position of the port authority vis-a-vis the activities of container terminals. This led to new insights on the role and contribution of a port authority in port and hinterland network development. This chapter discusses some of the main research outcomes of the work for these four research problems.

## 1 Developments in Multimodal Hinterland Networks

The research into seaports underwent a transition in the last fifteen years or so. While ports have always been considered as special locations in spatial structures [see, for instance (Hoyle and Hilling 1984)], the links between ports and their

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hinterland have not been studied much. This is surprising, since, in the field of port economics, it is commonly stated that ports compete not only on their sea access, but also on the quality of their hinterland access, see, for instance (Roso et al. 2009). Such links consist of, among others, a (not necessarily dedicated) collection of inland nodes and hubs, the mix of transport modes used to connect these locations to the seaport, the coverage of origins and destinations in the hinterland from the seaport and the organizational mechanisms that drive the flow of cargo to and from the hinterland.

In 1998, van Klink et al. (1998) suggested that ports might compete on the quality of their intermodal transport connections. Somewhat later, Notteboom and Rodrigue (2005) developed a framework for a more structured analysis of port–hinterland relationships. They position the port as a pivot linking two networks: the ocean shipping connections on the seaside, and the hinterland connections to various destinations and intermediate hubs on the landside. Their framework suggests that integrated transport structures such as corridors will develop to connect regional clusters in the hinterland to the seaport.

Around the years 2004/2005, ports in Europe were confronted with a sudden surge of containerized cargo from China. In the Port of Rotterdam, the fully automated terminals from ECT had great difficulty handling this strong sudden increase of incoming container flows, and in a few cases, when the stacks ran full, the AGVs became gridlocked, and the terminal systems came to a complete standstill. The solution for this seemed to be a mechanism that allowed the terminals to actively manage the levels of containers in their stacks, by pro-actively pushing batches of containers into the hinterland. Most multimodal hinterland transport systems were, and still are, pull systems: the receivers of containers call for transport. As a result, ECT began to take an active interest in strategically placed hinterland nodes, such as Duisburg in Germany, Venlo in the Netherlands, and Willebroek in Belgium. In addition, ECT began to search for transport partners to offer frequent services from Rotterdam to these hinterland nodes. In some cases (in particular Venlo), the network would offer several transport services per day. A final element of this concept was paperless transport, and extended releases for the container. This would facilitate speedy transport out of the seaport, while maintaining a high level of security and control over the containers in the network. While the container flow from China became more manageable and predictable, another development in the Port of Rotterdam gave new importance to the activities of ECT in the hinterland: the concessions for new terminals at the Second Maasvlakte area that were awarded to two competing terminal groups: APM Terminals and Rotterdam World Gateway. Suddenly ECT was faced with the prospect of intense competition on the seaside. This could perhaps partly be compensated with a strong competitive position in the hinterland.

In 2009, ECT sought to establish a multidisciplinary research group that would support the development of a strong multimodal hinterland network concept. This was the start of the ULTIMATE project, funded by the Dutch Institute for Advanced Logistics (DINALOG). ULTIMATE is an acronym that stands for “towards efficient multimodal hinterland networks”. This was at the same time the title and the aim of the project. Ultimate was a four year projects that funded or partly funded six PhD projects. A research agenda for the project consisted of four questions:

1. what are the operational consequences of integrating transport and cargo handling activities for supply chains?
2. how can new business models be incorporated in the design of hinterland networks?
3. what are the legal consequences of mixing transport and storage activities by container terminals?
4. what is the role and position of the port authority vis-a-vis the activities of container terminals?

This chapter discusses some of the main research outcomes of the work for these four research questions. First we will elaborate on the state of the art research in multimodal transport. Four subsequent sections will each deal with one of the research questions. This chapter ends with some concluding remarks and suggestions for further research.

## 2 Multimodal Transport Research

There are many terms for a transport solution that consists of more than one mode: intermodality, multimodality, combined transport, and more recent inventions, such as co-modal, exomodal and synchromodal transport. In this chapter, we consistently use multimodal transport, which we take to mean a transport solution, in which several modes of transport are used simultaneously and interchangeably. This is different from intermodal transport that usually means transport of standard cargo units by more than one mode of transport in a transport chain (which presumes the cargo unit is transferred from one mode to another, somewhere underway). Almost always, and especially with container transport, rail or barge transport is intermodal transport. This is because pre- and end-haulage for these modes is usually done by truck. Integrated multimodal transport is much less well developed.

There is a lot of research on intermodal transport. We briefly describe the transition of this research from the recognition of intermodality as an economics subject to a more elaborate analysis of intermodality as a competitive factor and a platform for advanced operational research. As a basic introduction into intermodal transport, we recommend (Vrenken et al. 2005). Much of this research is also relevant for the understanding of multimodal transport.

In the early 1990s, intermodal transport, and intermodal terminals began to be noticed by researchers as a phenomenon worthy of investigation. The European Commission had, at that time, adopted a transport system approach to its policy. Giorgi and Schmidt (2002) observe that after the adoption of the common market policy in the mid-1980s, the European Commission shifted from a strongly infrastructure based transport vision towards a vision on the economic structure of transportation. The European transport system was there to support the common market. Many elements in this transport system then received attention: railways, ports, pan-European motorways, short sea shipping, inland shipping, and, the integration of these modes in intermodal transport. Academic research followed this development, first with exploratory research, such as Konings (1996), on what intermodal terminals are, and Wiegmans et al. (1999), on the economics of intermodal terminals. Internationally, McCalla et al. (2001), among others, introduced a strongly geography oriented economic view on intermodal nodes, focusing on the relationship between these nodes and their surroundings. This type of research developed over the years in extensive transport network modelling efforts [see for instance Janic (2007), and more recently, Zhang (2013)].

Another, more strategically oriented research stream emerged from an early contribution of van Klink et al. (1998), who point out that intermodalism could and should be a competitive factor for seaports. This research is followed, among others, by Notteboom and Rodrigue (2005), who elaborate on the development of hinterland networks and place this development within the framework of general port development models. Strategy making of port authorities should thus include a vision on hinterland connectivity. This line of research was reflected in the ULTIMATE project; see Sect. 6. This line of research also seems to lead to fruitful new insights for management theory proper, as van der Lugt et al. (2013a) note, since port authorities are hybrid organizations of a particular kind.

While the term intermodal transport and intermodal terminal are relatively new, the notion of inland nodes that are connected to seaports is much older. In economic development circles, the term dryport has been used for a long time to indicate hinterland extensions of, often congested and poorly managed, seaports. Roso et al. (2009) revitalize this concept, and place it in the context of freight transport networks and intermodal gateways. Veenstra et al. (2012) contribute to this discussion by pointing out that the developments of extended gate networks are in fact modernized versions of dry ports in the hinterland of the Port of Rotterdam.

In the meantime, little attention was given to operations in intermodal and multimodal transport networks. Much of the research that emerged focused on isolated operational processes, such as crane operations, truck movements in terminals, or terminal equipment routing. In recent years, a more integrated view on multimodal transport operations was kicked off by surveys from Macharis and Bontekoning (2004) and, more recently, SteadieSeifi et al. (2014), who identify many white spots in the operations research literature for intermodal networks: network topologies, focusing on corridor structures in particular, integrating the planning of forward and backward hauls of transport modes, simultaneous planning of modes, distributed planning in complex networks, and solution methods for the more complicated planning problems all deserve attention.

In the ULTIMATE project, this research is extended in several ways. We extend the research on strategy making of port authorities, and consider several integrated multimodal network problems. In addition, we introduce a relatively new field of research in intermodal transport that deals with legal aspects of multimodality.

## 3 Integrated Planning of Transport and Cargo Handling

Multimodal transport is a complex logistical arrangement, in which the activities of multiple modalities, as well as one or more nodes or terminals need to be coordinated. Fazi (2014) unravels the mode allocation problem in choices for bundling, scheduling and routing. He also investigates the impact of container transport specific constraints that relate to time windows and due dates that are imposed by various stakeholders on the transport problem. Such constraints originate from the transport service itself—cut off times for a departing vessel—or from the use of the container on land. In particular these last constraints, i.e. the time before a full container needs to be collected in a terminal, and the time before the empty container has to be delivered back to the shipping lines—in practice the terms demurrage and detention are used—are particularly binding.

Fazi (2014, Chap. 2) considers the problem of bundling as many containers into one barge as possible. He models this problem as a variable size bin packing problem with time constraints, both in a deterministic and a stochastic variant. The model represents the realistic situation of an inland terminal that want to bring a number of containers from a seaport terminal to its own terminal inland, preferably by barge. The barge has a limited capacity, and the containers have deadlines by which the owners of the cargo need them. When the barge has to sail, remaining containers will be shipped by truck. Containers with a tight deadline will also be transported by truck. These problems are NP-hard, and they are solved with a heuristic. The results underline the negative impact of variability in the container flow, as well as time constraints, on the solutions of the problem. In this problem formulation, the actual impact of transportation was not considered.

The problem of mode allocation and scheduling for import containers is described as a heterogeneous vehicle routing problem (Fazi 2014, Chap. 3). This problem describes the situation in which an inland terminal has a number of barges and trucks, that need to collect containers at various terminals in the seaport. Again, time constraints for the containers are considered. A planner needs to allocate containers to barges and trucks in order to minimize transport time, while making optimal use of capacity and meeting the deadlines. Again a heuristic was developed to solve this problem. Some further analysis on the availability of information showed that more information does not always lead to better results. Sometimes, shorter time spans make better barge schedules. Fazi concludes from this that the choice of the planning horizon is critical for an efficient inland shipping operation.

A further extension of the mode allocation and scheduling problem is obtained by including export containers. Now the problem becomes a vehicle routing problem with pick-up and delivery and due dates for containers. This problem comes close to the problems inland terminal planners solve on a daily basis. Fazi deploys several heuristics and greedy algorithms to compare solution strategies. The greedy algorithms resemble how planners work in practice. The analysis shows that the heuristics perform markedly better than the greedy algorithms.

The practical relevance of Fazi's approach was proven in an experiment where a planner of one inland terminal in the Brabant Intermodal Group of terminals competed against Fazi's pick-up and delivery algorithm that includes import and export flows. This experiment showed that optimization of the operation did deliver better results than the planner, and could potentially save thousands of euros per trip.[1]

Finally, Fazi (2014, Chap. 5) studies the impact of demurrage and detention of containers. The due dates that shipping lines impose on their customers for full container pick up, and for empty container delivery back into an empty container depot are serious barriers to logistics optimization, and add significant costs to shippers' transport bills, as a result of penalties for violation of the due dates. Fazi shows that the due date and fee structure actually extends dwell time of the containers in terminals. He also shows that with the absence of demurrage and detention penalties, transportation costs could go down (because of less last minute trucking), and dwell time in the terminals (and therefore container turnaround time) could be reduced. Fazi also developed a new demurrage and detention cost function, i.e. a daily fee, chargeable from the moment of arrival of the container in the ocean terminal. This results in better transport costs, lower dwell times, and still a reasonable revenue for the shipping lines. This work sheds a whole new and critical light on the impact of the current demurrage and detention policy of shipping lines on multimodal transport in the Port of Rotterdam.

## 4 Network Design and New Business Models

As explained in the introduction, maritime container terminal operating companies have assumed a new role as multimodal transport network operator. They connect deep sea terminals with inland terminals via high capacity transport means such as barge (river vessel) and train. They have also extended the gate of their deep sea terminal to the gate of the inland terminal by the offering of (sea)port-to-(inland) port services and (sea)port-to-door services. These services compete with truck transport services when service frequencies are high enough. In his PhD research, Ypsilantis has discussed the role of new business models in the design of multimodal network services. In his work for the ULTIMATE project, he has considered (i) joint pricing and design of multimodal networks, (ii) dwell time analysis based on shared information, and (iii) the impact of collaboration on performance of network services.

First, Ypsilantis and Zuidwijk (2013) considered joint pricing and design of network services. In their research, they focused on Extended Gate networks, in which operators face the following three interrelated decisions: (1) determine which inland terminals act as extended gates of the seaport terminal, (2) determine

[1] w.a. Wiskundige module containertransport biedt kansen. Logistiek.nl, November 2014.

capacities of the transport services based on vessel capacities and frequencies of service, and (3) set the prices for the transport services on the network. Based on the work of Brotcorne et al. (2008), a bi-level programming model has been developed which jointly designs and prices extended gate network services. The network operator maximizes profit in anticipation of customers that route their cargo via minimum cost paths. The customers also have the option to purchase direct trucking services offered by the competition. Compared with the existing literature, Ypsilantis and Zuidwijk (2013) in addition incorporate time constraints and economies of scale.

Moreover, a heuristic is developed, similar to the one proposed by Brotcorne et al. (2008), that exploits the specific structure of the problem and that provides near optimal solutions to the problem in substantially less time. The ULTIMATE project provided data that could be used to model realistic scenarios, for which the authors study optimal network designs while comparing the aforementioned port-to-port and port-to-door services. One of the interesting results of the paper relate to the differences between the design of port-to-port services and port-to-door services. In the case of port-to-door services, the prices of services are determined by the competition. This implies that the design of the network is driven by cost minimization, and freight flows are consolidated through a limited number of extended gates to achieve economies of scale. In the case of port-to-port services, extended gates are opened to target particular market segments for which the competition leaves room for higher port-to-port tariffs. As a consequence, in the case of port-to-port services, optimization of network design truly comes down to revenue enhancement, and pricing and designing services cannot be distangled.

In the second contribution by Ypsilantis et al. (2014), joint data from a deep sea terminal operator and hinterland terminal operators allowed for an in-depth analysis of dwell times of import containers at sea ports and dry ports. The statistical analysis performed in the paper demonstrates that a considerable part of the dwell time variance is explained by factors that are under direct influence of the shipper. The analysis is based on real data, in particular milestone timestamps of import containers in the specific region in 2011.

A third contribution by Ypsilantis et al. (2014) relates to the design of barge services between a number of deep sea terminals and a number of inland terminals. Important principles in the design of multimodal transport services are the deployment of barges of certain sizes to reap economies of scale and the routing and circulation of these barges to attain frequencies of services on the network. The aim is to make the barge services on the network competitive with road transport, despite the costs and delays associated with the additional transshipments required. The authors develop a tight MIP formulation for the Fleet Size and Mix Vehicle Routing Problem, which is especially adapted to the mulitmodal barge service network design at hand. Particular attention is given to the benefits of horizontal cooperation between inland container terminals through capacity sharing. Results show that in the case of cooperation, not only costs are saved, but also service levels are enhanced.

## 5 Legal Consequences of Transport by Terminals

There are generally two standard ways in which hinterland transport can be arranged [see, for instance, Veenstra et al. (2012)]: either the shipping line extends its service to bring cargo from a seaport to a hinterland location, or the receiver of the cargo picks up cargo at the seaport and brings it to its own premises. The former is called carrier haulage, while the latter is called merchant haulage, referring to the buyer of the goods (i.e. the merchant) taking care of haulage. Usually both the merchant and the carrier hire a specialist to take care of the transport operations: a freight forwarder or transport operator.

In the development of multimodal transport networks, a new form of transportation is emerging: terminal haulage. In this transport concept, the terminal is the party that offers inland transportation as part of its service offering. Usually, the transportation offered by the terminal is limited in the sense that the terminal offers transport from its seaport location to one of its inland terminal locations. The final transport leg is then usually performed either by the merchant or by the inland terminal, by order of the merchant.

In transport law, in general, the roles of these parties, as well as the terminals that perform the loading and unloading operations, are carefully defined; see for more details, Haak and Kluwer (2010). In many countries in the world, transport law, as it applies to these different parties is mandatory law. In contracts, parties are not allowed to deviate from the stipulations in the law. This makes the development of new roles, such as a terminal operator that also offers a transportation service as part of its storage service, complicated. If the terminal moves a container from one terminal location to another one, without an order from its customer, it is not considered transportation, but an inter-terminal move, for which the standard limited liability of transport operators does not apply. The terminal is then fully liable for the value of the container. See for a legal discussion, the legal case of the General Vargas (Haak 1997).

As part of the ULTIMATE project, Susan Niessen has investigated several related legal questions. First of all, when is a transport operator responsible for the goods? Legally, this is from the moment of acceptance of the cargo until delivery of the cargo at destination. Delivery is a two-sided transaction, in which both the transport operator and the receiver of the goods have to interact, and the receiver actually takes control over the goods. Second, what is the legal obligation that a terminal undertakes in an extended gate service? In fact, an extended gate service consists of activities by five different legal actors: the stevedore, the storage keeper, carrier, forwarder or customs agent, and the legal treatment of problems such as damage depends strongly on which role was being performed at the time of occurrence of the problem (Niessen 2012).

The newly adopted Rotterdam Rules might provide a solution. Niessen investigated the role the terminals receive under the Rotterdam Rules regime (Niessen 2014). Terminals are so-called Maritime Performing Parties, under the Rotterdam Rules. This stipulation provides a better basis for the legal position of, among others, terminals than the current legal framework offers. At the same time, however, inland transport as an activity is excluded as part of the activities of the maritime performing party. The solution is a mixed contract, in which the terminal performs stevedoring activities as a maritime performing party, and inland transport as a (non-maritime) performing party, which is subject to applicable national law. What is required for the terminal offering a combination of cargo handling and transport services, is therefore a mixed contract that clearly identifies what activities is part of what legal role. Niessen recommends that the boundaries between activities are clearly identified in these contracts.

In a practical sense, Niessen's research has resulted in the formulation of intermodal transport conditions that are an improvement upon the amalgam of mode specific transport conditions that transport operators currently use. For the industry association VITO, representing Dutch inland intermodal container terminals, such a set of intermodal transport conditions were formulated.

## 6 The Role of Port Authorities

The extended gate concepts, as they are being developed by container terminals, as well as by ocean carriers, seem to by-pass port authorities. At the same time, port authorities should take a keen interest, since success of these concepts will enhance the competitive position of the port as a whole. As a result of this, the ULTIMATE project has addressed the topic through two lines of research. Larissa van der Lugt has concentrated on the shifting role of the port authority in governing a port area. Roy van den Berg has worked from inside the Rotterdam Port Authority to develop the strategy of the port authority towards carriers and terminal operators.

Verhoeven (2010) states that port authorities are publicly owned organizations in a competing world. The role most port authorities perform in this position is that of landlord: they own and control the port area, while mostly private parties invest in superstructure and perform activities such as cargo handling. Van der Lugt et al. (2013b) argue that the landlord model no longer covers the range of activities and roles of a port authority. Among these are activities related to the development of hinterland networks, facilitating private port companies and the creation of incentives for behaviour of port companies. In van der Lugt et al. (2013a), the authors elaborate on the particular nature of strategy making of port authorities. They characterize port authorities as hybrid, shared value organizations that are very interesting research subjects from a management research point of view, since their complex strategy making challenges some of the key concepts in management strategy literature.

Van den Berg provides an inside-out view on this complicated strategy making at a port authority. He investigates the modal split obligations that were included by the Rotterdam Port authority in the concessions on the Maasvlakte area in Rotterdam (van den Berg and De Langen 2014b). He finds that the modal split obligations do focus the attention of the container terminals on the quality of their hinterland networks, and in the case of the new terminals, has led to changes in the terminal design to better meet the obligations.

With respect to shipping lines' strategy, van den Berg and De Langen (2014a, c) find that a new service strategy is being introduced: the port-to-inland terminal (ILT) service, which lies somewhere in between the classic door-to-door and port-to-port services shipping lines have offered. They also find, surprisingly, that the port-to-ILT service actually competes more with the door-to-door service than with the port-to-port service. This is in contrast with earlier research [for instance, Franc and Van der Horst (2010)], that claimed the door-to-door service is not as sensitive to competition as the port-to-port service. Port authorities, for which shipping lines are important clients, need to be aware of these competitive dynamics. Apart from excellent cargo handling facilities, they could and should strive to offer a portfolio of inland terminals that have all the relevant capabilities and facilities to enable the shipping lines' new value proposition.

The results of this research have translated back into the Rotterdam Port Authority's strategy making, in various areas. First of all, the Port of Rotterdam has considered the importance of the quality of hinterland connections a key element in the design of the operational cooperation between the competing terminals at the Second Maasvlakte. Instead of treating these terminals as independent entities, the Port Authority has tried to forge an operational cooperation agreement between these terminals on inter-terminal transport, and on the joint handling of container trains. Second, the better understanding of the strategy of ocean shipping lines has directed the focus on inland terminal development by the Port Authority in especially southern Germany. The Port Authority closely cooperates with the container terminals in these efforts.

## 7 Concluding Remarks

The extended gate concept is an important development in the Port of Rotterdam. The research in the ULTIMATE project has contributed significantly to the understanding of the potential and the bottlenecks for extended gate services. Both the research of Fazi (Sect. 3) and Ypsilantis (4) showed that collaboration among inland terminal operators and between deep sea and inland terminal operators creates efficiencies and enhanced service levels. Moreover, Panagiotis demonstrated that design and pricing of network services are intertwined. Fazi showed that optimisation of the hinterland container network brings benefits for transport and terminal operators. In addition, Fazi showed that current demurrage and detention policies of ocean carriers are detrimental to this optimization process. Van der Lugt and van den Berg (Sect. 6) showed that port authority strategy making could play an important role in the further development of hinterland networks of terminals and ocean carriers, and this will contribute to the overall competitive position of the seaport. Niessen (Sect. 5), finally, pointed out some serious legal impediments in the development of extended gate concepts for ocean terminals. She also presented a solution, which is a hybrid contract under the new Rotterdam Rules regime.

All of this research also has practical applications, which are either within research on the short term, or are important ambitions for the medium term.

Many research questions remain. Much work needs to be done in the development of heuristics to solve more advanced hinterland transport problems, as well as more elaborate multimodal network design problems. Strategy making of port authorities turns out to be fruitful research area in business strategy, due to the particular nature of port authorities as hybrid organization in the public-private arena. In the legal profession, role changes for transport and logistics businesses are a complicated research area in need of more work. The ULTIMATE project focused on one particular role change: from terminal to transport operator. In addition, the complicated legal matter of a uniform framework for multimodal transport remains to be solved. The Rotterdam Rules provide a complicated solution for only one instance: intercontinental transport with an ocean leg. In addition, the Rotterdam Rules refer to national law for the multimodal transport leg, in which different legal structures exist for different modes of transport. What is required is a new framework that integrated all these frameworks into one.

The definition of new logistics concepts that re-establish new business models and roles in supply chains has impacts beyond the logistics realm. The project ULTIMATE has spurred a new research agenda where logistics, legal, business, and public administration aspects play a role and interact. For instance, both horizontal and vertical integration and collaboration have logistics and legal consequences. The ULTIMATE project has shown the benefit of a multidisciplinary approach, where mutual understanding between researchers strengthens their own effort, and, at the same time, provides more practical outcomes for business parties. As such, the ULTIMATE project has set a significant step in the direction towards integrated multimodal hinterland networks.

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