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# Intermodal nodes and external costs: Re-thinking the current network organization

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A B S T R A C T

Modern ports are part of intermodal and international networks and have great effects at regional level, influencing both the efficiency of the local markets and the external costs of the served industries. Several studies point out that modern ports need to be included in an efficient network system in order to exploit all their potential. Further, concerning the role of the ports within the whole supply chain, key elements are the location and organization of intermediate facilities – such as logistic parks or inland ports – that heavily affect the effectiveness of the logistic corridors. The accuracy in designing a logistic system can have a big impact on the externalities induced by the transportation, too. New and adequate infrastructures can reduce transport congestions, pollution and accidents.

The proposed study evaluates potential locations of inland ports that might serve a market through different alternatives, in terms of transport modes, costs and distances. The present study has the additional goal of including the external costs in the decision process. For this scope, a linear programming model with both continuous and binary decision variables is given. The required parameters and the constraints of the problem are shown, together with real data concerning the Italian north-western regions and the related infrastructures. Thanks to the proposed model, different intermodal freight logistic networks are compared; in particular, a sensitivity analysis on both the rail capacity and external costs is performed. Note that the outcomes can be used for improving current transport policies that might foster a more efficient and less impacting hinterland transport solution.



## 1. Introduction

International transports are based on complex networks of services that involve a plurality of actors and transport solutions in order to make possible efficient globalised origin – destination connections (e.g. Meersman, Van de Voorde, & Vanelslander, 2009). For these reasons, all possible routes between a port and its own hinterland represent strategic links able to foster the port efficiency and its competitiveness (e.g. Tongzon, 2009). Several evidences show that well connected hinterlands might increase port competitiveness (e.g. Ferrari, Parola, & Gattorna, 2011) and efficient uses of intermodal transport – in terms of either logistic parks or inland ports – might enlarge port catchment areas (e.g. Notteboom & Rodrigue, 2008).

Note that the connections between a port and its hinterland are not just important for efficiency reasons, but also for the overall costs arising from different transport solutions; such costs account not only direct private cost components but also external ones (e.g. Arnold, Peeters, & Thomas, 2004; Iannone, 2012). Starting from Pigou (1932), external costs of any economic activity gain importance due to the divergence between the perceived "private" costs of a specific economic behaviour and the real overall costs, quite frequently including external costs, such as the environmental ones. In the maritime academic literature this issue has been seldomly studied until the '90s, when it became one of the major concerns (e.g. Lakshmanan, Nijkamp, Rietveld, & Verhoef, 2001; Meersman, Van de Voorde, & Winkelmans, 1998); in particular, many studies tried to evaluate the discrepancy between the private perceived costs of a given transport solution and its actual cost for the society. Cost estimations varied over the time due to the difficulties in clearly evaluating both the external effects and their range of impact (e.g. Maibach et al., 2008). Despite this, external costs have recently been deeply studied, also under many EU projects, aiming, for instance, at assuring their internalization (e.g. eurovignette); however, only few studies try to associate external costs to the optimization of intermodal transport solutions (e.g. Arnold et al., 2004; Janic, 2007).

In the recent literature, many studies focus on the effective flow distribution in a determined hinterland (e.g. Ambrosino & Sciomachen, 2012; Notteboom & Rodrigue, 2008; Racunica & Wynter, 2005), the problem of internalizing the transport costs (e.g. Grosso, 2011) or determining the market areas of intermodal (rail-road) container terminals

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(Limbourg & Jourquin, 2010); relevance is given to the impact of recent EU transport policies on both the cost internalization and its effects on the transport patterns (e.g. Ferrari & Tei, 2012; Limbourg & Jourquin, 2009). Recent studies have analysed the most effective flow distribution in a given port hinterland (e.g. Iannone, 2012), taking into account not only the transportation costs but also the external ones (Santos, Limbourg, & Carreira, 2015) studying the problem through a case study approach. As recently remarked (Troch et al., 2015), actions should be taken to make rail freight and intermodality a valuable option. The present paper aims to contribute in this sense: a mixed integer linear programming (MILP) model has been developed for designing a distribution network with the aim of: i) locating inland ports within a specific hinterland; ii) defining the optimal distribution flow. Two competing transport modes are considered, namely rail and road; such transport modes can be combined generating the additional intermodal transport modality. The location and flow distribution decisions are taken with the aim of minimizing the overall distribution costs, expressed by the transportation and externality costs and those associated with the inland ports. A real case scenario, referring to the North Western Italian regions, is deeply analysed; the data used have been provided by the Italian National Customs for the Ligurian ports (Genoa, La Spezia and Savona) and refer to 2011 (the last full available year). Moreover, infrastructural data have been collected for being able to draw the network analysed by the proposed model; more precisely, the whole highway and railway networks of the Italian regions under study have been considered. Further, three candidate inland ports have been analysed to choose the best one/ones for defining the distribution network, as it will be described in the following sections. Finally, in this study we refer to an inland port as a facility characterized by "a rail (or a barge) terminal that is linked to a maritime terminal with regular inland transport services" having an intermodal terminal within its boundaries, as defined by Rodrigue, Comtois, and Slack (2013).

The paper is structured as follows. After this introduction, Section 2 focuses on the regional and port characteristics of the considered area, while Section 3 is dedicated to the model description. Section 4 presents the results applied to the proposed case study and discusses them also performing a sensitivity analysis on the optimal solution. Finally, Section 5 addresses conclusions and provides insights for future research developments.

## 2. Regional framework

In Italy the freight distribution is mainly based on an extensive use of the road transport; this mode is also dominant in the volume of cargo generated by the domestic seaports (e.g. Consulta Nazionale per l'Autotrasporto e la Logistica, 2011). The statistics produced by the European Environmental Agency (EEA, 2010, 2015), as well as several relevant literature (e.g. Iannone, 2012) and the last National Logistics Plan (Consulta Nazionale per l'Autotrasporto e la Logistica, 2011), highlight how such an unbalanced modal split deeply impacts on the environment, due to the dominant role of the road transport. To give an idea, according to Pastori (2015), only <10% of the cargo handled by the port of Genoa is shipped by rail. This issue has been deeply analysed; consequently, several national projects are now trying to deal with the externalities generated by trucks (e.g. De Martino, Erricchello, Marasco, & Morvillo, 2013). While modal shift policies are often based on incentives to make modal alternatives more convenient – as for the Ecobonus that in Italy characterizes the Motorways of the Sea (e.g. Tei & Ferrari, 2012) – less attention has been paid on policies able to internalize the external costs. This issue is mainly due to both the poor political consensus given by these latter policies and the difficulty of applying them. Nevertheless, the definition of more efficient transport solutions – considering the overall induced costs – is essential in order to minimize the above mentioned costs.

Concerning the cost internalization, Maibach et al. (2008) make evidence that the road transport results much more expensive when the external costs are considered along with the private ones. Among the main external costs, the "Handbook on estimation of external costs in the transport sector" (Maibach et al., 2008) takes into consideration three main components: pollution (atmospheric and noise related one), risk (e.g. increasing probability to have an accident) and congestion. Other specific external costs have been also considered in the handbook; however, not all of them can be easily adapted to all European contexts or transport solutions, as for the climate change effects.

It is important to underline that external costs not only relate to "environmental" aspects but also to some side effects that can have a great impact also on the network efficiency; among these, the main one is the congestion, that can heavily affect the efficiency of the transportation system. For this reason, many authors (e.g. Janic, 2007) show that external costs internalization might positively impact on the rationalization of the flows, also incentivizing the use of intermodality due to a better mix among the transport solutions.

### 2.1. The collected data

This study starts with the analysis of the freight distribution of three of the major Italian ports, that is Genoa, La Spezia and Savona. In fact, in 2014 Ligurian ports accounted for about 35% of the Italian container traffic – being the greatest gateway port region in Italy – and for >18% of the overall Italian port throughput (Assoporti, 2015). Port hinterlands are quite similar, even if some regions concentrate a great share of the three ports' activity, as shown in Fig. 1, where NUTS-3 regions are used as basic geographical unit to map the distribution flow. In particular, Fig. 1 shows the import distribution of the containerised cargo, as it is used in the proposed analysis.

In the present study we focus on the import flow of containerised cargo. In fact, presently in Italy the containerised cargo is the only one able to be competitive using both the rail and the road transport solutions (with different level of performance); further, ports, as well as inland ports, are used to aggregate all the flow coming from the same point and going to close destinations.

Considering the 2011 spatial distribution of the import containerised cargoes handled by the three Ligurian ports (see Fig. 1), it is important to underline a substantial overlapping in the catchment areas between the ports of Savona and Genoa – basically corresponding to Piedmont (in particular Turin and Cuneo) and Lombardy (in particular Milan) regions; La Spezia seems to be more focused on cargoes directed to the Emilia-Romagna region. Despite the geographical concentration of part of the traffic, another peculiarity of the considered ports is the wide range of the catchment area. For instance, the smallest studied container port (i.e. Savona) attracts cargos from the Venice region, despite the presence of closer ports specialised in container activity, such as Venice and Trieste.

Moreover, all the studied ports have several plans to expand their container activities thanks to new terminals; therefore, it is crucial to study the possibility of using the rail network for the cargo distribution.

As said, the strict majority of the freight is currently delivered by road (according to Pastori (2015) and the related port authorities' statistics, road solutions account for >90% in Genoa and Savona and >80% in La Spezia) while only two inland ports are presently active; one inland port is located in the Alessandria Province and receives flows from the port of Genoa, while the second one is in Milan and is mainly used by La Spezia. Several plans can be found in the port websites discussing the possibility of using other inland ports in order to serve other markets or to enlarge the railway activity.

Considering the network data about infrastructural constraints and distances, official statistics have been used in order to collect all the required information from the official databases published by the Ligurian Region (i.e. Regional Logistics Plan) and the infrastructure managers (i.e. *Rete Ferroviaria Italiana* for railways and *Autostrade per l'Italia* for the motorways). Then, considering the collected data, the road and rail networks have been derived: as underlined by the Regional Logistics