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An economic logistics model for the multimodal inland distribution of maritime containers

Abstract

"Interports" are defined as common-user facilities located in the hinterland of one or several seaports. They represent an innovation posing challenges and opportunities for operators involved in freight transport, freight forwarding, value-adding logistics, manufacturing and trade.

At the interports a range of services may be offered beyond both the simple multimodal switching of load-carrying units from one type of carrier to another and the warehousing of goods. Examples are customs operations and technical controls, cargo consolidation/deconsolidation, advanced quasi-manufacturing and distribution logistic services, and even wholesale and retail trade. Customs services contribute to seamlessly integrated operations between seaports and interports (the "extended gateway" concept).

Mathematically, we identify the "*interport model*" as an extension of the conventional multimodal and multicommodity transhipment problem. Main purpose of the network model is to highlight and measure the advantages that logistic agents can enjoy in routing maritime containers through the interports. The model minimizes the sum of all container-related logistic costs throughout the entire port-hinterland distribution network, subject to balancing conditions at all nodes and capacity constraints over railway links. The logistic costs include transportation costs (by road and railway), terminal and customs operation costs, and in-transit inventory holding costs.

We present an empirical application portraying the intermodal and logistic "first-tier" network in the Campania region, Southern Italy. Naples and Salerno are the container seaports of the region; the relatively recently constructed terminal, customs, warehousing and processing facilities at Nola and Marcianise are recognized as interports. Major Italian regions and cities are the other inland destinations for the container traffic handled in the Campania seaport cluster. Interports face a local demand for containers, and they can perform intermodal and customs functions. Both interports and locations endowed with a railway terminal can serve as intermediate transhipment nodes for traffic towards other inland destinations.

The numerical prototype was programmed and solved using the GAMS (General Algebraic Modeling System) computer code. The results confirm the importance of the regional off-dock and inland logistic system for the distribution of international maritime containers flowing through the Campania seaport cluster. The future competitiveness of the regional seaports and their hinterland distribution system will depend on a further improved supply of interport services.

Key words: inland container logistics, interports, multimodal transport, customs, mathematical programming, virtual nodes

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1. Introduction

The containerization and evolution of the transportation industry have made off-dock terminals and inland ports increasingly popular as means for boosting the seaport capacity[1]. Non-essential terminal activities such as customs clearance and controls, storage, sorting and distribution of load-carrying units can be transferred from seaports to off-dock and inland sites. Customs services, in particular, contribute to seamlessly integrated operations between seaports and such intermodal sites (the "extended gateway" concept[2]). As a result, container dwell times[3] and congestion at the seaports can be dramatically reduced. In addition, off-dock terminals and inland ports make it possible to shift cargo away from congested roads to railways (or inland waterways, where available) through frequent, fast, reliable, cost-effective and large capacity shuttle services.

Italy was the first European country to legally conceive of and financially support inland ports as first-tier and common-user facilities in sea-land intermodal logistic networks. The term used to indicate an inland port is that of "interport", as an abbreviation of "interior port". Some Italian interports serve in the double role of satellite terminals and inland ports (e.g. the interports of Nola and Marcianise in Campania region, as well as the interport of Cervignano in Friuli Venezia Giulia region).

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[1] It is possible to distinguish on-dock, near-dock, off-dock and inland sites according to the relative location of such intermodal sites in relation to a seaport terminal (Ashar, 2004). A further classification was introduced by Roso (2007) and Roso *et al.* (2006), who distinguish among distant, mid-range and close dry ports. Instead, Rodrigue and Notteboom (2009) distinguished satellite terminals and inland terminals (or inland ports), the former being located in the immediate vicinity of seaport terminals, while the latter are closer to the market, i.e. they are located in more remote areas and linked to long distance corridors. Furthermore, satellite terminals are usually featured by a high degree of syncronization with seaports, while the degree of syncronization tend to be lower for inland terminals. Notteboom and Rodrigue (2009) further investigated the role of such terminals in regional freight logistics, also by putting into evidence topics related to the setting-up and the exploitation of inland terminal facilities in Europe and North-America.

Other literature contributions on such topics are, for instance, the followings: Ballis (2006), Harrison (2007), IBI Group and Hatch Mott MacDonald (2006), Jaržemskis and Vasiliauskas (2007), Kirkland (2007), Leitner and Harrison (2001), Meidute (2005), Podevins (2007), Rahimi *et al.* (2008a), Rimiene and Grundey (2007), Slack (1999), Theys *et al.* (2008), Tsamboulas and Dimitropoulos (1999), UNESCAP (2007), Woxenius *et al.* (2004).

From a functional perspective, it is possible to distinguish between facilities providing only intermodal and cargo handling services, and those operating as broader logistic zones, i.e. as intermodal and logistic centres where a more or less wide range of value adding services is supplied by different bodies. In all cases, such facilities have the potential to simultaneously reduce truck traffic and congestion and promote jobs, economic growth, and logistic integration inland.

[2] The extended gateway concept is based on the idea of moving some container seaport functions, in particular customs inspection and clearance, to an off-dock or inland location which becomes an integral part of the seaport itself, freeing up additional space and capacity to be employed for on-dock and other priority port activities. A theoretical analysis of the extended gateway concept is provided by Rodrigue and Notteboom (2009), and Visser *et al.* (2007). The contributions by the China Intermodal Transport Services to the Interior Project – ITSIP (2003), Hayut (1980), Tioga Group (2006), and UNCTAD (1991) clarified important aspects related to the concept.

[3] Dwell time is the length of time a container remains at a terminal before being loaded onto a transportation vehicle (ship, train, truck, barge) for further distribution. It can be a large proportion of the total transit time in a door-to-door multimodal distribution process, and it is a critical factor influencing the capacity both at seaports and other intermodal nodes. It is affected by customs and other technical and administrative control procedures, as well as by both the terminal operators' service level, and supply chain management strategies based on the employment of the terminals as places for the low-cost warehousing of goods. Relevant issues were dealt with by Merckx (2006) and Rodrigue and Notteboom (2009).

Interports represent an innovation posing challenges and opportunities for operators involved in freight transport, freight forwarding, value-adding logistics, manufacturing and trade. At the interports a range of services may be offered beyond both the simple intermodal switching of load-carrying units from one type of carrier to another and the warehousing of goods. Examples are customs operations and technical controls, cargo consolidation/deconsolidation, advanced quasi-manufacturing and distribution logistic services, and even wholesale and retail trade.

Our study deals with the inland multimodal distribution of maritime containers through a regional load center network system encompassing seaport and interport nodes. In the pages to follow, we formulate and solve an economic optimization model for the inland logistics of containers imported through the seaports located in Campania region in Southern Italy. The containers can transit both through the regional interports and extra-regional locations equipped with a railway terminal before reaching their final destinations.

Naples and Salerno are the container seaports of the region; the relatively recently constructed terminal, customs, warehousing and processing facilities at Nola and Marcianise are recognized as interports. Major Italian regions and cities are identified as the other inland destinations for the container traffic handled in the Campania seaport cluster. Our work aims at measuring the logistic advantages and/or drawbacks arising from both shifting the seaport exit of imported containerized cargoes to regional interports, and employing intermodal solutions for the hinterland distribution.

The *interport model* should be understood as a novel extension of the conventional mathematical programming network model to logistic theories and evidence related to the "Port regionalization"[4], the "Supply chain terminalization"[5], and the extended gateway concept. It is a large-scale, linear, static, multimodal and multicommodity[6] transhipment model with capacity constraints that identifies possible optimal choices concerning the regional off-dock and inland container logistics economy.

The programming problem minimizes the total logistic cost of the distribution operations over the inland network, subject to flow balancing conditions at all origins, intermediate and destination nodes, as well as to capacity constraints over the railway links. The model solves for the annual multimodal inland traffic demand among different nodes (seaports, interports, etc.) for full and empty units disembarked in Campania, and more generally it estimates the modal split of inland distribution traffics of containers imported in Italy by sea through the Campania

4 Notteboom and Rodrigue (2005) identified a "port regionalization" phase representing a new stage in port development featured by a strong functional interdependency and even joint development of specific seaports and selected multimodal logistic platforms in their hinterland.

5 Rodrigue and Notteboom (2009) introduced the concept of "supply chain terminalization" to underline the high integration of intermodal terminals in commodity supply chain management practices, which goes well beyond the conventional role of the terminals. Shippers have begun to use seaport and inland terminals as places for storing goods at low cost. It gives the commodity supply chain a higher level of flexibility, allowing to lower the warehousing costs for consignments. In such a situation, high dwell times can be increasingly associated with deliberate supply chain management strategies. Especially in the seaports, due to relevant capacity constraints, terminal operators react to the supply chain terminalization phenomenon both by imposing restrictions in terms of free time and increasing storage charges. Consequently, the practice in developed port systems and more generally in regional load center networks is that if the shippers need prolonged storage, they have to go look for the facilities outside the marine terminals, because the seaports are only transit facilities.

6 The model considers the traffics of both full and empty containers.

seaports. Total logistic cost includes transportation costs (by road and railway), terminal and customs operation costs, and in-transit inventory holding costs.

The model gives a mathematical representation of the possibility to shift the container releasing seaport operations to the regional interports through an extended gateway system based both on the container carrier haulage by railway under customs bond between seaports and interports, and on the customs clearance at the interports. If an interport has an authorized customs area, the interport itself may be indicated in the bills of lading as the final destination of the international multimodal transport, and the railway transfers between the container seaports and the interport will occur under customs bond on behalf of shipping lines.

The construction of interports and other off-dock facilities is intended to reduce the build-up of cargo at the seaports, and to reduce queuing times. The time dimension is accounted for in several ways in our work, through the consideration of:

- average dwell times for empty containers at seaports and interports;
- average dwell times for full containers by customs control type (automated computerized control, documentary control, physical inspection, X-ray scanning) at seaports and interports;
- average dwell times at seaports for full containers to be cleared by customs at interports;
- free-of-charge container storage times at seaports and interports;
- demurrage charges incurred at seaports and interports[7];
- the time duration of multimodal transport operations over the network;
- opportunity costs and economic-technical depreciation costs for the containerized goods[8].

The most crucial elements in this list is the average dwell time at the seaports. At Naples it varies from 9.4 days to 23.8 days in the case of cleared full containers. Customs procedures are the most important factors determining such figures.

Interports are examples of Schumpeterian innovations dramatically changing the layout of the logistic networks. They involve huge investments and relieve congestion at seaports. The

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7 Demurrage is the daily charge for terminal storage of a container beyond the agreed free time.

8 These are in-transit inventory holding costs depending on the value of the containerized goods (expressed in Euros/full TEU), as well as on both the time duration of the logistic operations and a reference interest rate. By taking into consideration both the average customs declared value of imports in Campania in the first half of 2007 (equal to 15,934 Euros/TEU, based on a calculation performed through the employment of data provided by the Italian Customs Agency), and an yearly rate of 35%, it has been obtained an in-transit inventory holding unit cost for full containers handled in Campania seaports equal to 15.3 Euros/full TEU/day or 0.64 Euros/full TEU/hour. Naturally, such values have only an average and prudential meaning. In fact, it is necessary to consider the potential possibility of customs bill declarations which do not match what effectively transported and which succeed to elude the controls. In such a case, the average unit value of the containerized import cargoes could be even higher.

The modal and nodal choice is influenced by the value of the carried goods and therefore by the indirect monetary costs related to the time of the distribution operations. The higher the value of the goods, the more privileged will be speedy logistic solutions because of high inventory holding costs. Vice-versa, for low value goods it will be preferred logistic solutions aimed at minimizing the direct monetary costs of the transportation and handling operations. Issues related both to the value of time and inventory holding in container distribution were investigated, for example, by Drewry Supply Chain Advisors (2007), Foschi (2004), Hausman *et al.* (2005), Leachman (2006), Notteboom (2008), Notteboom and WU (2008).

purpose of the *interport model*, as presented here, is to provide a mathematical description and analytical tool for such innovation. The equilibrium flows of containers are determined by the capacity constraints, as well as by supply chain terminalization strategies, and definitively by the performances in terms of internal logistic costs of both the container releasing operations at the nodes and multimodal transportation over the port-hinterland network.

We believe that our model could be a useful tool supporting industrial and territorial logistic decisions, particularly within a strategic planning context. The program can simulate long term alternative scenarios in terms of infrastructure and services supply, demand characteristics, and government and industrial policies. Naturally, the tool can also be adapted and employed to identify the most appropriate distribution location solutions in relation to the traffics from a seaport to specific inland trade basins.

Actually, as we shall see, the numerical solution to the *interport model* for the Campania region pinpoints many current shortcomings of the Campania logistic system, for instance: lacking customs facilities at the interport of Marcianise, suspension of railway connections at the port of Salerno, congestion and high container dwell times at the port of Naples, and low rates of utilization of the existing railway capacity from seaports and interports. It will also provide clues for the improvement of current performance. We shall thus be able to make an overall diagnosis and assessment of the current situation of the Campania logistic system for the importation of maritime containers, and to propose possible steps of improvement.

Sub-section 1.1 presents a brief literature review, mainly devoted to some optimization models in the field of container logistics. Section 2 introduces the network for imported containerized goods through the Campania region: the seaports, the interports, and the railway and truck connections with other Italian nodes. Section 3 explains the customs procedures at the seaports and at the interports. Section 4 describes the *interport model* by way of a somewhat stylized example, and indicates the nature of the quite large mathematical programming problem that we have actually solved with real data. Section 5 reports on the obtained numerical solution. Section 6 sums up the results and introduces several extensions of the model.

1.1 Antecedents

Spatial optimization models available in the literature that can be employed for the containerized traffic industry are not numerous. For instance, Aversa *et al.* (2005) employed a multicommodity mixed integer hub-and-spoke model identifying the optimal location of a hub port on the East Coast of South America. Crainic (2003) dealt with the planning and management issues and models for long haul freight transport systems. Crainic and Kim (2007) illustrated several issues related to the containerized intermodal transport, as well as several applied mathematical modelling methodologies. Cullinane *et al.* (2002) employed a single commodity, multimodal and multiobjective mathematical programming capacitated model to simulate, based on time and cost criteria, the optimization of the flows of full containers imported in China. Deidda *et al.* (2008) developed an integer programming model concerning the so-called "street-turn" or "triangulation" strategy of a shipping line. Kim *et al.* (2008a) developed a multimodal mixed integer programming model to optimize the flows of full containers imported and exported in Korea. Kim *et al.* (2008b) developed a multimodal linear programming model to optimize the flows of full containers imported and exported in Korea. Lee *et al.* (2006) developed a capacitated multicommodity linear programming network model to analyze the containerized maritime flows between Asian ports and over the two-way USA-Far East and Europe-Far East routes. Luo (2002) and Luo and Grigalunas (2003) developed a spatial economic, multimodal simulation model dealing with the containerized transport of 30 cargo categories imported and exported through US container seaports. Racunica and Winter (2005) developed an optimization model to tackle the problem of increasing the share of rail in intermodal transport through the use of hub-and-spoke networks. The model is a generalization of the hub location problem with non-linear and concave cost functions on different segments. Rahimi *et al.* (2008b) investigated the inland port location problem in the five counties surrounding Los Angeles. Van Duin and Van Ham (2001) presented a three-level modeling approach for the design and organization of intermodal transport services, taking into account the different perspectives of shippers, terminal operators, agents, consignees and carriers. They developed, among the others, a linear programming model for a network optimization based on cost and whose results indicate opportunities for inland terminal development in Utrecht and Leiden/Alphen.

Our present work builds on earlier researches reported in Iannone (2006a; 2006b), Iannone *et al.* (2007), Thore (2007), Thore and Iannone (2005). For complete background materials, see the doctoral dissertation of Iannone (2008).

The *interport model* represents an adaptation to the inland container traffic industry of the hub-and-spoke model identified in Thore and Iannone (2005)[9]. Some specific features distinguish it from other spatial models available in the literature. In particular, the customs issues and the container releasing operations at the nodes of the investigated regional load center network system are explicitly modelled. Furthermore, the model also features a road supply sub-model for the quantification of the road transport times at national scale according the Road Code regulations.

2. Inland container distribution through the Campania regional logistic system: functional and topological features

Campania is a region located in the Southern Italy, the Italian "*Mezzogiorno*". It is endowed with an extensive road and railway network, and it is crossed by the Berlin-Verona/Milan-Bologna-Naples-Messina-Palermo TEN-T railway axis planned at European Union level. Also, Campania is expected to play a significant role in the future Euro-Mediterranean Free Trade Area, by establishing easy interconnections between European industrial and consumer areas, and the shores of the Northern Africa and Middle East. The first-tier sea-land intermodal logistic system in Campania is currently based on the Tyrrhenian regional seaports of Naples and Salerno, and on the interports of Nola and Marcianise (Iannone *et al.*, 2007).

The current geographical and commercial inland basin of the Campania seaports is exclusively a national basin. Figure 1 depicts a conceptual schema of the set of nodes, multimodal links, and logistic processes that features the import container distribution through the Campania regional logistic system. This schema can be translated into Figure 2 which is a

[9] Thore and Iannone (2005) outlined the principal properties of the transhipment problem in a hub-and-spoke type network configuration, with particular reference to its primal and dual mathematical formulations, its economic interpretation, and the complementary slackness conditions. Possible scale economies phenomena related to the concentration of the flows were not taken into consideration.

theoretical topological representation of the containerized inland logistic network investigated by the *inward interport model*. The network features the following nodes:

- Seaport nodes at Naples and Salerno. They serve as entry points for full and empty containers imported by sea, to be distributed by road and railway over the national hinterland. Each seaport node has terminal and customs functions.
- Interport nodes at Nola and Marcianise. They are served by truck and rail, and have a local demand of containers disembarked in the seaports. Furthermore, they may provide terminal and customs services, and can serve as transhipment nodes for some traffic relations from the seaports towards other inland final destinations. Finally, the interports may provide quasi-manufacturing value-adding logistic services[10].
- Final destination nodes with railway terminal which are served by truck and rail from the Campania logistic system. They can also perform the role of intermediate transhipment nodes (railway-to-truck and truck-to-truck) for some traffic relations from both the seaports and interports towards other inland final destinations.

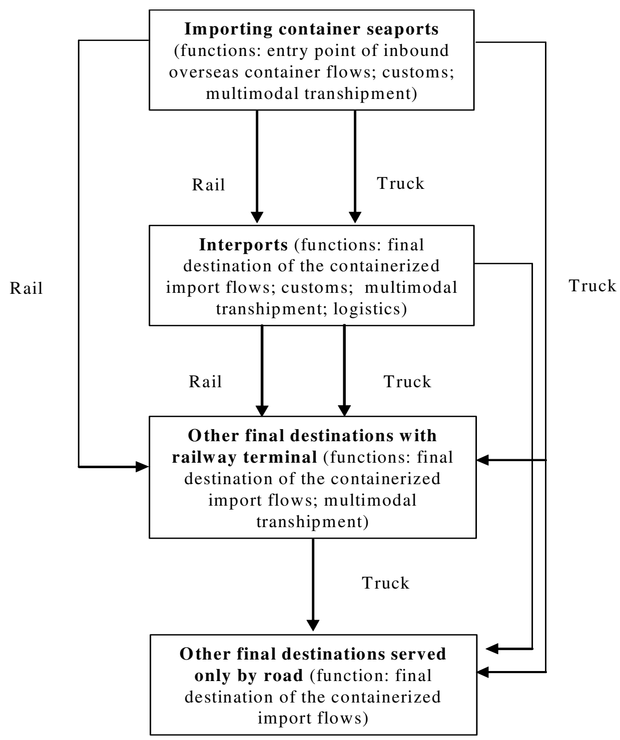

Figure 1. Distribution of maritime containers imported through the Campania regional logistic system: a conceptual schema

[10] The quasi-manufacturing value-adding logistic function of the interports can be dealt within an *interport model* with a maximizing objective function.

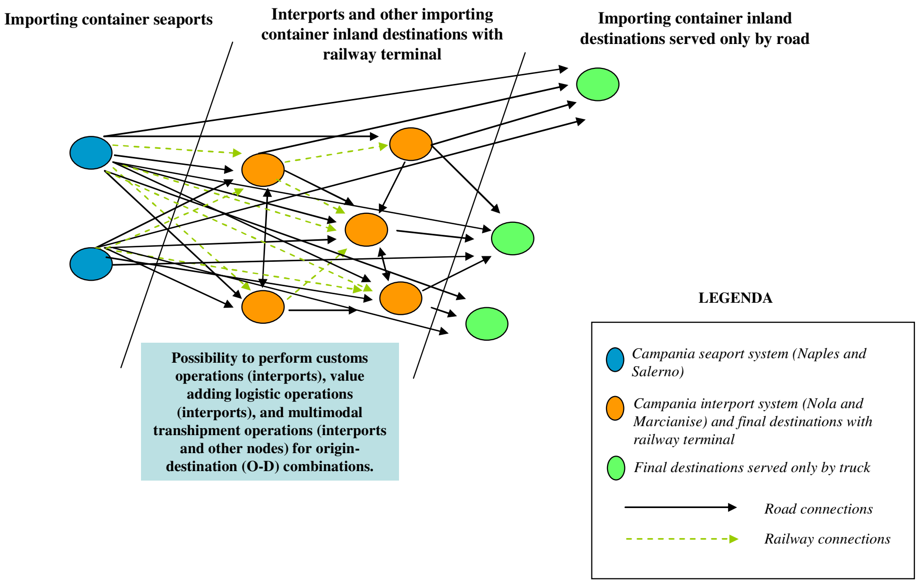

Figure 2. Inland distribution of maritime containers imported through the Campania regional logistic system: theoretical topological features of the investigated network

Refer now to Figure 3 which exhibits a detailed map of the network for the inland distribution of containers disembarked in Campania. Such network features 24 real nodes and 163 real links (road + railway). The seaports at Naples and Salerno are connected by truck to all the inland locations of the network. Naples is connected by railway to the interports and to some final destinations with a railway terminal; Salerno is connected by rail to the Nola interport and to Bari city/terminal. There is no rail connection between Salerno and Marcianise. The interports are connected by road to all the other inland locations of the network, and by railway to some final destinations with a railway terminal. The other container demanding destinations reachable by railway from the nodes of the Campania regional logistic system can serve by road some inland destinations which could be alternatively served directly from Campania. Definitively, by considering the configuration of the investigated network, all the inland nodes served by railway can perform the function of inland multimodal transhipment node for various O/D combinations.

Customs clearing may take place either in the seaports of Naples and Salerno themselves or in the interports of Nola and Marcianise. The Campania network of imported maritime containers thus forms an extended gateway system based on railway connections under customs bond and under the full responsibility of the shipping lines (carrier haulage) over the routes Naples-Nola, Naples-Marcianise, and Salerno-Nola.

Currently, carrier haulage under customs bond is possible only towards/from Nola interport. In the future, a fully operational customs status of Marcianise interport is expected as well.

Since December 2005 the rail freight services from/to Salerno port have been suspended due to a serious accident that happened on the urban segment of the railway connection between Salerno city and the port rail terminal. In the mathematical *interport model* there are railway connections from Salerno port both towards the interport of Nola and the city of Bari (Apulia region, Southern Italy), thus simulating the operational situation prior to the accident. But at the interport of Marcianise it is not possible to clear full containers disembarked in the port of Salerno because of the unavailability of a railway connection between the two nodes.

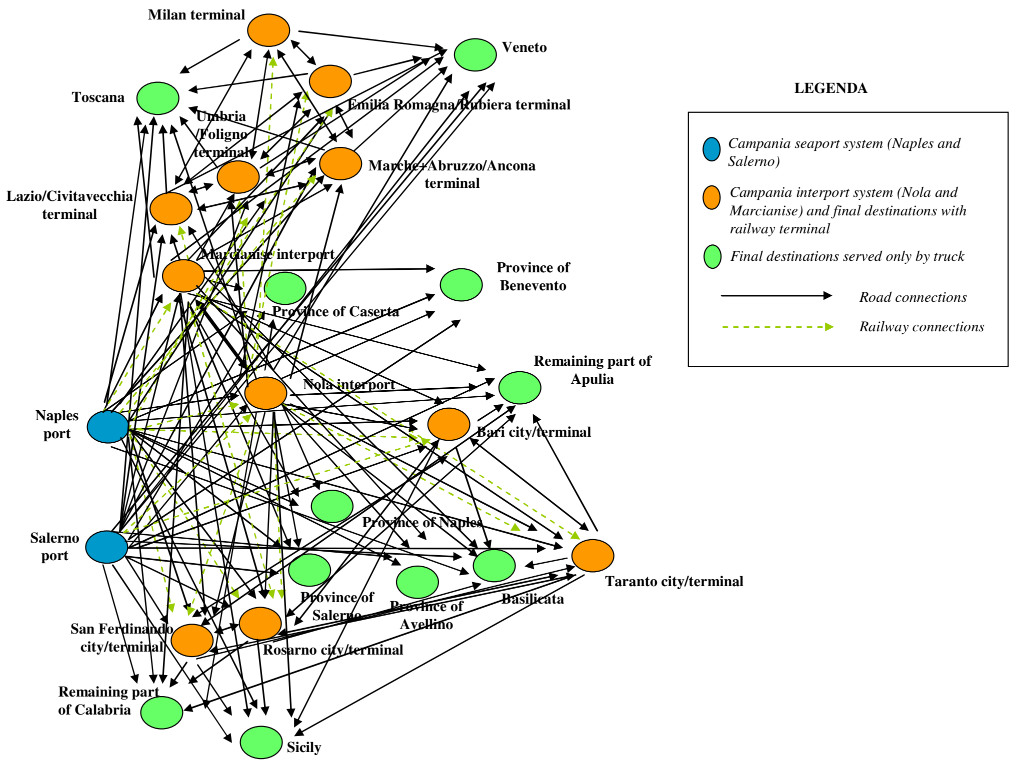

Figure 3. Configuration of the inland distribution network investigated by the interport model

In addition, the network investigated by the model also includes the following rail connections operated in years preceding 2007: Naples-Foligno, Nola-Foligno, Nola-Rubiera, Marcianise-Taranto, Marcianise-Rosarno, and Marcianise-Civitavecchia. Definitively, the rail container services included in the model are all those operated in Campania during the years 2005-2007.

A novel aspect of our model is the use of "virtual nodes" for modeling the whole range of container traffic related functions which can be performed by each interport. Virtual nodes have identical geographical location but involve different interport processing activities. In the present work, we identify two virtual nodes at each interport:

- the processing of containers arriving from the seaports by road or railway as either full cargo units already cleared by customs or empty cargo units;
- the customs clearance and processing of full containers arriving from the seaports by railway under customs bond and on behalf of the shipping lines (carrier haulage).

Both nodes perform an intermediate intermodal function. But only one of them performs a customs function as well. It can be reached only by railway. Instead, only to the other virtual node is attributed the local interport demand of full and empty containers arriving from the seaports. Both virtual nodes have the same outbound inland multimodal connections. Finally, in order to model the eventual possibility of clearing in each interport the full containers originating in a regional seaport and destined to importing operators located in the interport itself, it is admitted the one-way road transport at a nil generalized cost between the virtual node with customs function and the other one without customs function.

3. Customs clearance of maritime containers: the case of Italy and Campania region

The customs procedures strongly affect the equilibrium level and therefore the distribution of containerized flows over the logistic networks. Subramanian (2001), Subramanian and Arnold (2001), and Hausman *et al.* (2005) have shown that institutional issues such as customs inspection and clearance, technical clearance, and document processing are among the most important factors in the cost and time of shipments, more important even than the physical conditions of roads or rail.

Customs clearance and examination procedures include checking the accuracy of the shipping documents, calculating import duties and taxes, locating containers, moving them to the customs area for inspection, submitting to inspections, taking samples of goods for analyses, ensuring that illegal goods are not being moved, returning the container to the stacking yard or quay and recording. They all generate direct and indirect costs increasing the total logistic cost over the shipping network. As reported in Wilson (2009), customs and administrative procedures have substantial effects on trade flows. Unfortunately, customs fraud in the containerized trade has also become more and more alarming. Containers are sometimes employed in the illicit traffic of highly taxed or prohibited goods.

We briefly describe the customs clearing process in Italy. A shipper needs to get a container cleared by customs before picking it up from (or delivering it to) the marine or inland terminal operator (whenever an inland terminal has a customs status and it is connected by railway to the seaport). The process includes electronic and/or paper forms, the payment of applicable duties and making the cargo available for inspection if required[11]. In particular, the operator has to present to the customs office a declaration bill as recognized by European Union, the so-called "Unique Administrative Document" (UAD). It contains all the elements required to identify and categorize the cargo/consignment[12]. The declaration, which can also be submitted via the internet, is processed by the Italian Customs Agency's information system[13], which performs a computerized risk analysis based on the central Italian Customs Agency data-base. The data-base contains data on economic operators (importer or exporter, and declarant)[14], and on the particular economic operation (import or export), e.g.. the origin and the destination of the goods, their type and quality, customs code, nomenclature, etc. The risk analysis identifies 4

[11] The Member States of the European Union all employ the same customs declaration model and a common Customs Code. The Code lists also the basic common legislation related to the customs controls.

[12] The procedure to be followed from the compilation of the customs declaration up to the clearance of the goods is nearly similar in all the Member States of the European Union.

[13] The so called "*A.I.D.A.*" (*Automazione Integrata Dogana e Accise*) and the "*Circuito Doganale di Controllo*".

[14] EU provisions permit the issuance of a reliability certificate (Authorized Economic Operator - AEO) once the national customs authority in charge of controlling operators has verified that the operator meets the professional compliance requirements defined by the member countries. Obtaining the AEO status reduces the degree of risk posed by the operator.

risk categories (green, yellow, orange, red). The meaning of the colours is tied to the type of controls defined by the system as it follows:

- "Green light", i.e. automated computerized documentary control (AC), which means that all necessary controls have already been performed by the information system. The container is automatically cleared and needs neither inspections nor other types of customs controls. The AC label adds neither time nor time related costs to the shippers' clearance procedure.
- "Yellow light", i.e. documentary control (DC), which implies the necessity to materially control the commercial documentation accompanying the container in order to verify the coherence with the Unique Administrative Document. The DC label prolongs the clearing process and consequently the shippers will suffer time-related inventory costs. If the customs clearance time exceeds the free time either in ports or interports, storage charges for containers (demurrage charges) will accumulate as well.
- "Orange light", i.e. scanner control (SC), which implies the necessity of an X-ray scanning of the container[15]. The label SC adds direct monetary costs to the shippers' clearance process (mainly because of the intra-terminal handling and road transport costs), plus time-related inventory costs. As before, if the customs clearance time exceeds the free time either in ports or interports, storage charges for containers (demurrage charges) will accumulate as well.
- "Red light", i.e. physical inspection (PI), which implies the opening of the container and a partial or total examination of its content by customs agents. The PI label adds direct customs inspection and intra-terminal handling and road transport costs for shippers, plus time-related inventory costs. If the customs clearance time exceeds the free time either in ports or interports, storage charges for containers (demurrage charges) will accumulate as well.

Moreover, the clearance of a container in any seaport or interport can also involve other types of technical and administrative procedures and controls, for example: sanitary controls, veterinary controls, and so on[16]. There has been a wide-ranging debate in Italy about the possibility to better coordinate and unify the different procedures and inspections of containers at the first-tier intermodal nodes. The proposals include setting-up customs "one-stop-shops" for integrating different processes, that today may require up to 73 documents per customs declaration (being released by over 20 bodies).

In 2007, in the integrated Italian customs system 88% of the containerised goods has been cleared after an automated computerized control (AC), 6% after a documentary control (DC), while the remaining 6% after a material control of cargoes (of which the 11% through a

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[15] In Italy, there are 28 scanners located in the main national ports and interports that enable the analysis of the load units in a non-invasive fashion. Controls may be in-depth or determine a new type of control (such as the physical inspection of the goods, including sampling for chemical analysis). The images obtained with the scanner are forwarded to the so called "Matrix" command center to feed an image database of reference, employed to adjust and facilitate the analysis of the successive scanned images. The outcome of the control proceeding is forwarded to the Customs Control Circuit and contributes to the risk analysis.

[16] For instance, health officials may want to inspect foodstuffs, plant materials and animals to ensure that they are healthy, fit for consumption or for transport.

scanner control). The detailed data for the ports of Naples and Salerno, in Campania region, during the same year are reported in table 1. The data show a higher incidence of customs controls in the port of Naples than the national average.

Table 1. Incidence of customs controls on containers cleared at the ports of Naples and Salerno in 2007

Year 2007	Naples port	Salerno port
Automated computerized control - AC (containerized imports)	59.0%	84.0%
Documentary control - DC (containerized imports)	11.0%	11.0%
X-rays scanner control - SC (containerized imports)	5.0%	1.0%
Physical inspection - PI (containerized imports)	25.0%	4.0%
Automated computerized control - AC (containerized exports)	71.3%	87.0%
Documentary control - DC (containerized exports)	10.0%	10.0%
X-rays scanner control - SC (containerized exports)	3.1%	0.5%
Physical inspection - PI (containerized exports)	15.6%	2.5%

Source: Italian Customs Agency - Rome, Campania-located terminal operators and freight forwarders, 2008

The total inland traffic of full containers disembarked at Naples in 2007 was equal to 183.622 TEUs, while the total inland traffic of full containers embarked was equal to 148.954 TEUs. At Salerno the disembarked full containers in the same year amounted to 71,681 TEUs, while containerized exports were 160,835 TEUs.

The higher number of customs controls in the port of Naples derives from elements contained in the customs declaration bills and which are deemed potentially high-risky. In particular, at the port of Naples a high number of customs controls takes place of containerized cargoes from China and South-East Asia, mainly textiles, footwear, leather goods - cargoes that directly compete with Italian industry. At least the 70% of the textile imports from China to Italy transits through the port of Naples. Figure 4 shows the evolution of the annual rate of incidence of the containerized import traffics from China in the port of Naples.

During the last years, large volumes of counterfeit goods coming from China have been seized at major Italian ports. Campania is the Italian region mainly affected by this phenomenon, particularly as it regards the traffics through the port of Naples. But the real issue is that in the port of Naples the clearing process can take plenty of time. This means increasing monetary costs for shippers due to extra-moves costs, demurrage charges, high inventory costs, and so on.

Table 2 lists the average unit dwell times according to the different cases of customs controls (AC, DC, SC, PI) on full containers cleared at the Campania seaports in the year 2007. The sample data reported - which are averages between values for full load units leaving out by road and values for full load units leaving out by rail - approximately refer to the container dwell times by single types of customs controls occurred in combination with other types of technical and administrative controls (veterinary controls, sanitary controls, etc.). Comparisons have been made with the port of Rotterdam, where the release of a container may take 3-7 days at most.

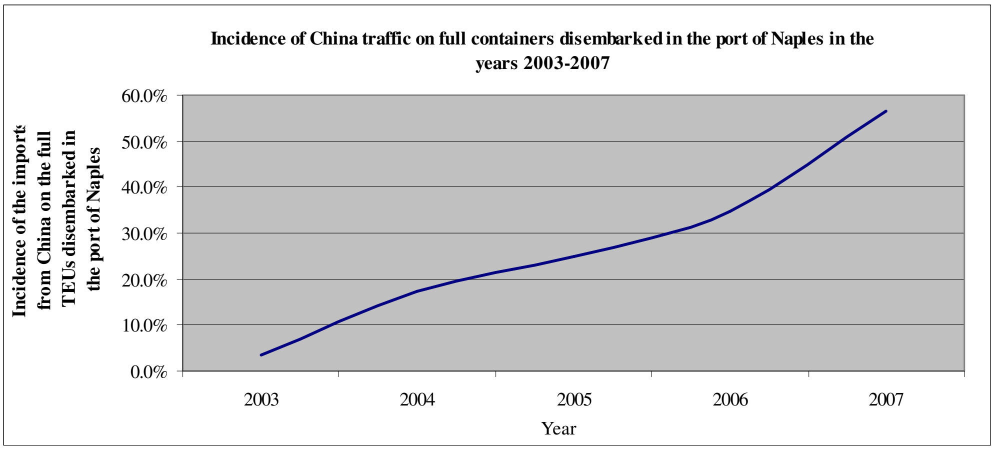

Figure 4. Incidence of China traffic on full containers disembarked in the port of Naples (years 2003-2007)
Source: Eurostat data-base, 2008

Table 2. Average dwell times of imported containers at the ports of Naples and Salerno in 2007 (sample data)

Average dwell times of the imported containers	Number of days/TEU	Number of hours/TEU
Automated computerized control (AC) - port of Naples	9.4	225.6
Documentary control (DC) - port of Naples	14.5	348.0
Scanner control (SC) - port of Naples	23.8	571.2
Physical inspection (PI) - port of Naples	22.6	542.4
Automated computerized control (AC) - port of Salerno	4.5	108.0
Documentary control (DC) - port of Salerno	5.0	120.0
Scanner control (SC) - port of Salerno	7.4	177.6
Physical inspection (PI) - port of Salerno	7.0	168.0

Source: Campania-located terminal operators and freight forwarders, 2008

The higher average generalized port cost in the port of Naples, compared with other European or Italian seaports, is due to a current under-dimensioning of the customs facilities and staff, as well as lacking coordination of the various bodies in charge of controls. For example, according Co.Na.Te.Co.[17] data, on 2nd May 2007 the Customs officials physically inspected 71 containers over a total of 671 containers to be inspected in the port of Naples. At the end of the day the Customs officials established other 114 physical inspection to be executed. So the remainder containers to be inspected on the next day, 3d May 2007, were 714. Definitively, the process proves to be cumulative, with serious consequences in terms of congestion and operational difficulties.

A partial solution to such congestion (due to accelerating volumes of trade, as well as to customs organizational problems and facility constraints) can be the employment of the regional interports for both the quick release of the containers at the seaports and the possibility of complying the customs formalities outside the seaports themselves and at more favourable

[17] In the port of Naples, Co.Na.Te.Co. is the company who manages the marine container terminal owned both by the Swiss shipping line MSC and the Chinese shipping line COSCO.

generalized cost conditions. To fully exploit such benefits, it is necessary that the off-dock and/or inland sites have a customs authorized resident area and are connected by railway to the seaports.

The customs authorities may consider interports as an "extension" of marine terminals, which means operators do not have to wait for customs officials to release the containers at the seaports. If an interport has a declared customs area, the shipping line may not even have to draw up a customs document for the follow-up declaration for transit from the seaports. The shipping line will issue its own bills of lading assuming full responsibility for transportation costs and conditions between the point of origin/destination and the off-dock/inland site (the so called "carrier haulage"[18]), and the container transport between the seaport and such site will be provided by railway under customs bond. In compliance with the current customs regulations in force in Italy, only the railway transport may allow the necessary conditions of fiscal safety related to the inland carrier haulage of maritime containers which have not been nationalized yet through the customs clearance.

Customs operations at the interports can help to reduce the dwell times of containers in deep-sea ports. The interports may accept or deliver containers under the steamship bills of lading in the same fashion as the marine terminals. The dwell time in the port of Naples for full containers to be transported under customs bond and on behalf of shipping lines from/to the inland can be assumed equal to 1.7 days.

In 2007, for the first time, a traffic of approximately 625 TEUs was carried by railway under customs bond on behalf of the shipping line CMA-CGM from the port of Naples to the interport of Nola. Such traffic was equal to the 10% of the total railway traffic of full containers from Naples to Nola (6.245 TEUs). The remaining share was in greatest part merchant haulage destined to warehousing facilities located in the interport itself.

Table 3 reports the observed dwell times of the maritime containers released in the Campania interport system. The Nola's sample data approximately refer to the single types of customs controls occurred in combination with other types of technical and administrative controls (veterinary controls, sanitary controls, etc.). Furthermore, at least the same performance levels could be hypothesized at the Marcianise interport in the case of a fully operational customs bonded status of its intermodal terminal. Currently, the intermodal terminal operating company at Marcianise has not been yet authorized at operating a so called "A3 area", that is a customs bonded zone for both the handling and storage of imported and exported containers to be cleared. Moreover, in the Marcianise interport there is no currently available X-ray scanner yet. For the purpose of the calculations to be reported in the present paper, however, we have assumed that facilities at Marcianise would parallel those already installed at Nola.

Table 4 contains observed data concerning the time duration of physical customs inspections at the interport of Nola. The amount of time taken into consideration includes the time elapsing from the telematic submission of the customs declaration bill to the final customs approval of the possibility to release the container. From January to June 2008 the average

[18] As documented by Rodrigue and Notteboom (2009), and Van der Horst and De Langen (2008), in Northern Europe has been recently emerging the "terminal operator haulage" practice as well. Such practice is based on the responsibility of the marine terminal operator en route between the seaport and inland terminal, and therefore on a more active involvement of the marine terminal companies in hinterland connections by establishing closer relationships with shipping lines and inland operators.

number of days taken by Customs to both inspect and authorize the release of a container at the interport was equal to 2 days (including holidays).

Table 3. Average dwell times of imported containers in the Campania interport system in 2007 (sample data)

Average dwell times of the imported containers	Number of days/TEU	Number of hours/TEU
Automated computerized control (AC) - interport of Nola	4.6	110.4
Documentary control (DC)- interport of Nola	5.1	122.4
Physical inspection (PI) - interport of Nola	7.1	170.4
Scanner control (SC) - interport of Nola	7.5	180.0

Source: Campania-located terminal operators, freight forwarders, and third party logistics providers, 2008

Table 4. Physical inspections (PI) of imported maritime containers at the interport of Nola in the period January -June 2008

Month	Total No. of imports	Total No. of PI on imports	PI %	No. of dissimilarities	Diss. %	Total No. of days for PI	Average No. of days for a PI	No. of PI concluded in 1 day	% of PI concluded in 1 day	No. of PI concluded in more than 7 days	% of PI concluded in more than 7 days
January	645	111	17.2%	4	3.6%	194	1.8	40	36.0%	0	0.0%
February	592	95	16.1%	4	4.2%	234	2.5	19	20.0%	3	3.2%
March	578	91	15.7%	6	6.6%	181	2.0	18	19.8%	0	0.0%
April	455	51	11.2%	2	3.9%	84	1.7	23	45.1%	1	2.0%
May	550	77	14.0%	1	1.3%	114	1.5	29	37.7%	0	0.0%
June	421	73	17.3%	5	6.9%	185	2.5	33	45.2%	4	5.5%
Total	***3,241***	***498***	***15.4%***	***22***	***4.4%***	***992***	***2.0***	***162***	***32.5%***	***8***	***1.6%***

Source: Customs Office "Napoli 2" – Territorial Operational Division of Nola, 2008

To sum up, customs facilitations represents a decisive innovation for Italian regional logistic systems. Such initiatives are among the few alternatives that Italian seaports and regional load center networks have at their disposal to prepare themselves to face with both the expected future traffic patterns and the challenges posed by rapid reconfigurations of global logistics and multimodal transportation networks.

4. Mathematical formulation

We construct a large-scale transhipment model for the economic analysis and strategic planning of the inland logistics of the maritime containers transiting through the seaports and interports of the Campania region. The model is multimodal, allowing for both road and rail transportation, and multicommodity, covering both full and empty containers. It features capacity constraints explicitly formulated for railway links. The objective of the mathematical program is the minimization of all container-related logistic costs throughout the entire port-hinterland distribution network. The model takes into consideration transportation costs, in-transit inventory holding costs, terminal and customs operation costs.

To introduce matters we present a stylized example of an *interport model* along the same lines as in Thore and Iannone (2005). That is, a linear model with demand specified by O/D pairs. In such a case, the demand requirements are then not just that a certain total arrives at each destination (irrespective of its origin seaport node), but that all individual customers are satisfied, both at the origins and at the destinations[19]. The example includes the novel concept of "virtual nodes" (see Section 2).

In the figure 5 there are two originating nodes *1* and *2* (conveniently identifiable as the port of Salerno and the port of Naples, respectively), an interport featuring the two virtual nodes *3* and *4* (node *3* representing the processing of either empty containers or full containers that have already been cleared by customs at the seaports, node *4* representing the customs clearance and processing of full containers arriving from the seaports by railway transport under customs bond and on behalf of shipping lines). Finally, there are three other distant final destinations, that is the nodes *5*, *6*, *7*. Only the nodes *5* and *6* have a railway terminal. The virtual interport node *3* has a local demand of containers as well; therefore it is also a final demand node of the model.

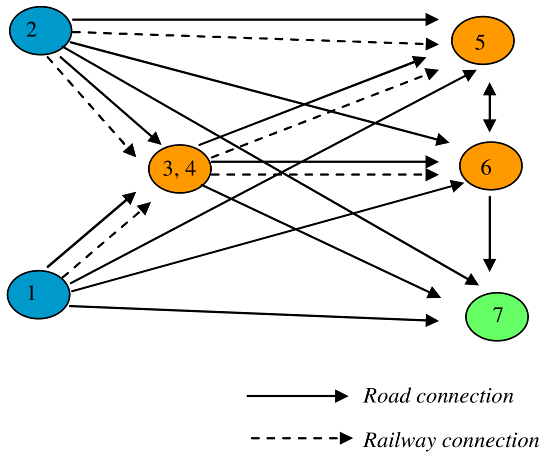

Figure 5. Stylized model of multimodal logistic network with interport virtual nodes

The simple example shown here is "unicommodity", i.e. it involves only the logistics of full containers disembarked in the seaports and to be distributed overland. The generalization to multiple container types is immediate and need not delay us here. Introduce some mathematical notations as it follows:

I: set of all the nodes of the network = $\{1, 2, 3, 4, 5, 6, 7\}$

L (I): set of the first-tier intermodal nodes of the regional load centre network for containers cleared at the seaports = $\{1, 2, 3\}$

P (L): set of the seaport nodes of the regional load centre network = $\{1, 2\}$

Q (L): set of the "virtual" interport nodes without customs function = $\{3\}$

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[19] To deal with this situation, it is possible to formulate as many separate programs as the origin nodes of the problem. Consequently, there will be as much vectors of unknown variables as the origin nodes. The separate programs can be joined together into one "master" program, which can also be defined "multicopy" or "multipage" program. Common capacity constraints form "coupling" conditions.

$D\ (I)$: set of the "virtual" interport nodes with customs function = $\{4\}$
$Z\ (I)$: set of all the inland locations demanding containers imported through the origin seaport nodes = $\{3, 5, 6, 7\}$
$E\ (Z)$: set of all the inland locations (excluding the interports) demanding containers imported through the origin seaport nodes = $\{5, 6, 7\}$
$R\ (E)$: set of all the demanding inland locations not equipped with a railway terminal = $\{7\}$
$H\ (I)$: set of nodes with function of inland transhipment centre = $\{3, 4, 5, 6\}$
M: set of the admitted inland transportation modes = $\{rail, truck\}$
T: set of the road linear infrastructures = $\{motorways,\ remaining\ road\ types\}$ [20]
A: set of the railway links = $\{1\_(3+4),\ 2\_(3+4),\ 2\_5,\ (3+4)\_5, (3+4)\_6\}$ [21]
$\left[D_{pi}\right]$: a column vector of container demand specified in number of full TEUs by origin-destination node pair (that is from each seaport node $p \in P$ towards each node $i \in I$)
$\left[c_{ij}^{m}\right]$: a row vector of generalized unit transport costs (in Euros/TEU) for mode $m \in M$ between nodes $i, j \in I$
$\left[f_{p}^{m}\right]$: a row vector of weighted average generalized unit costs (in Euros/TEU) of the releasing operations for imported full containers cleared at seaport node $p \in P$ and leaving out the seaport node itself by the transport mode $m \in M$ [22]
$\left[g_{p}\right]$: a row vector of generalized unit costs (in Euros/TEU) of the releasing operations for imported full containers leaving out the seaport node $p \in P$ by railway under customs bond and on behalf of shipping lines (carrier haulage) towards a virtual interport node with customs functions
$\left[h_{d}^{m}\right]$: a row vector of weighted average generalized unit costs (in Euros/TEU) of the releasing operations for imported full containers arriving by railway under customs bond and on behalf of shipping lines (carrier haulage) from the seaport of Salerno $(1 \in P)$ in the virtual interport node

[20] Such set is employed with reference to road distance parameters considered together with the assumed average road driving speeds in order to compute the road driving times, and definitively the total travel times by road over the links of the investigated network.
[21] This set is employed with reference to the railway capacity constraints of the model. See the column vector [b_a]. The capacity constraint of each railway connection from/towards each interport jointly considers the railway links from/towards each of the two corresponding virtual nodes.
[22] The weighted average generalized unit port costs are computed by taking into consideration direct and indirect costs of the releasing operations according the different probabilities observed in Campania seaports for the different customs control types (AC, DC, PI, SC).

(with customs function) $d \in D$, and subsequently cleared and leaving out the virtual interport node itself by the transport mode $m \in M$ [23]

$\left[j_d^m \right]$: a row vector of weighted average generalized unit costs (in Euros/TEU) of the releasing operations for imported full containers arriving by railway under customs bond and on behalf of shipping lines (carrier haulage) from the seaport of Naples $(2 \in P)$ in the virtual interport node $d \in D$, and subsequently cleared and leaving out the virtual interport node itself by the transport mode $m \in M$ [24]

$\left[k_q^m \right]$: a row vector of generalized unit costs (in Euros/TEU) of the releasing operations for imported full containers already cleared in a seaport node and leaving out the virtual interport node (without customs function) $q \in Q$ by the transport mode $m \in M$

$\left[b_a \right]$: a column vector of the maximal number of containers which can be transported over the railway link $a \in A$ during the planning horizon

$\left[x_{ij}^m \right]$: a column vector of inland shipments of containers disembarked in the seaport node $1 \in P$ and forwarded between nodes $i, j \in I$ by transport mode $m \in M$

$\left[y_{ij}^m \right]$: a column vector of inland shipments of containers disembarked in the seaport node $2 \in P$ and forwarded between nodes $i, j \in I$ by transport mode $m \in M$

The objective of the programming model is:

$$\min \ W =$$

$$\begin{aligned}
&\sum_{i \in I} \sum_{j \in I} \sum_{m \in M} c_{ij}^m \cdot (x_{ij}^m + y_{ij}^m) + \sum_{p \in P} \sum_{z \in Z} \sum_{m \in M} f_p^m \cdot (x_{pz}^m + y_{pz}^m) + \\
&+ \sum_{p \in P} \sum_{d \in D} g_p \cdot (x_{pd}^{rail \in M} + y_{pd}^{rail \in M}) + \sum_{q \in Q} \sum_{e \in E} \sum_{m \in M} k_q^m \cdot (x_{qe}^m + y_{qe}^m) + \\
&+ \sum_{d \in D} \left\{ \sum_{z \in Z} \begin{matrix} \left[(h_d^{truck \in M} \cdot x_{dz}^{truck \in M}) + (j_d^{truck \in M} \cdot y_{dz}^{truck \in M}) \right] + \\ + \sum_{e \in E} \left[(h_d^{rail \in M} \cdot x_{de}^{rail \in M}) + (j_d^{rail \in M} \cdot y_{de}^{rail \in M}) \right] \end{matrix} \right\}
\end{aligned} \qquad (1)$$

The sets *Q* and *D* introduce the feature that we have called “virtual interport nodes”, which have the same geographical location but offer different services. A full container arriving

[23] Such weighted average generalized unit interport costs are computed by taking into consideration direct and indirect costs of the releasing operations at the interports according the different probabilities observed in the port of Salerno for the different customs control types (AC, DC, PI, SC).

[24] These weighted average generalized unit interport costs are computed by taking into consideration direct and indirect costs of the releasing operations at the interports according the different probabilities observed in the port of Naples for the different customs control types (AC, DC, PI, SC).

at a seaport node $p \in P$ can either be cleared by the customs right away, in which case it can proceed to an inland demanding location $z \in Z$, including virtual nodes without customs function ($q \in Q \subseteq Z$). Or it can have its customs clearance delayed, in which case it has to proceed by railway to a virtual node $d \in D$. In this manner, the shipper may avoid costly delays at seaport nodes awaiting access to customs clearance.

The objective function of the full model that we have constructed and solved is a straight-forward generalization of (1). The full model features 26 nodes and 219 admitted links (by taking into consideration, among the others, 2 virtual nodes per each regional interport and their related links). It minimizes the total logistic cost for the distribution of full and empty containers throughout the national hinterland network of the Campania seaports. Briefly, the considered cost items concern:

- the operations of container loading and unloading onto/from transportation vehicles at the seaport and interport nodes (container handling charges);
- the container storage operations at the seaport and interport nodes (demurrage costs in function of the dwell time for full containers to be transferred by railway under customs bond and on behalf of shipping lines from seaports to interports, and demurrage costs in function of the dwell times for empty containers, automatically controlled full containers, documentarily controlled full containers, physically inspected full containers and X-ray scanned full containers at seaports and interports, to be forwarded by road or railway);
- the additional direct costs for physical inspections (PI) and X-ray scanner controls by customs at the seaport and interport nodes (additional direct customs costs)[25];
- the in-transit inventory holding costs related to the dwell times of full containers at the seaport and interport nodes;
- the generalized internal costs of the road and railway transport of full containers over the admitted links of the network (direct transportation costs + in-transit inventory holding costs related to the time duration of transport operations);
- the internal cost of road and railway transport of empty containers over the admitted links of the network[26].

The cost of transport toward a generic node includes the cost of the terminal operation related to the offloading of the container from the vehicle at the end of the trip. Moreover, the cost of road transport from the final destination nodes equipped with a railway terminal (excluding the interport nodes) towards other demanding nodes comprises the cost of terminal operations both at the departure and arrival.

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[25] Since for simplification and illustrative purposes, in the *interport model* it is assumed that all the container transiting through the Campania seaports carry legitimate cargoes, and therefore succeed in positively passing the customs controls. Moreover, the model does not take into consideration the payment of customs duties related to the value of the imported goods.

[26] Future experiments with the *interport model* could include a leasing cost parameter, which is a time-related component of the total logistic cost for container distribution.

Total travel time by road is equal to the driving time plus the time for rests and stops prescribed by Road regulations under the "1 driver on board" hypothesis. The number and time duration of rests and stops to be observed in a container transportation by truck have been calculated in function of the driving time. The same computational procedure employed by Aponte *et al.* (2009) has been adopted.

Obviously, the full model includes more parameters than the mathematical notations presented above. Furthermore, it is subjected to flow conservation constraints at all origin, intermediate and destination nodes, as well as both to non-negativity constraints on the decision variables and capacity constraints over railway links. Other constraints in the full model: 1) set to zero all variables involving non-existing links over the logistic network[27]; 2) permit one-way road transport with a nil generalized cost for full containers between the two virtual nodes at each interport, that is the road transport between $4 \in D$ and $3 \in Q$.

All in all, our model features 863 unknowns and 168 constraints. It was programmed and solved with the GAMS (General Algebraic Modeling System) computer code, using the solver CPLEX. Main empirical input data were directly provided by various bodies and firms involved in the intermodal and logistic industry at regional, national and international level[28]. Other input data have been derived from internet web-sites, specialized press, scientific literature, and industrial studies. Generally, excluding some rail links (Salerno-Nola, Salerno-Bari, Naples-Foligno, Nola-Foligno, Nola-Rubiera, Marcianise-Taranto, Marcianise-Rosarno, and Marcianise-Civitavecchia), all the data of the model refer to the year 2007.

5. Optimal solution and discussion

The aim of the *interport model* consists of measuring the possible benefits related to both the employment of Campania interports and intermodal solutions for the inland distribution of full and empty maritime containers handled in the Campania seaports.

The solution of the model delivers the optimal flows of full and empty containers along all road links and all rail links. The equilibrating mechanism is governed by the terms of both direct and indirect logistic costs of the releasing operations at the nodes, and therefore by both the capacity of nodes and the supply chain management strategies of the shippers, as well as by

[27] Similarly to all the large-scale network models, also the *interport model* uses a sparse data structure, that is a structure based on data matrices with relatively few non-zero entries. It seems appropriate to remember and put into evidence that (road and/or railway) connections are not allowed between some nodes of the network investigated by the model. Therefore, a value equal to zero has been assigned to the spatial, temporal and economic attributes of the forbidden links, and appropriate constraints have been finally formulated as well.

[28] In particular: the Rome-located Italian National Customs Agency, the Nola interport-based Customs Office, the Port authorities of Naples and Salerno, the Centre for Transportation Culture at the Ente Autonomo Volturno (a Campania government-owned holding for regional public transportation planning and management), the management companies of the major maritime container terminals located in Campania (Co.Na.Te.Co. and SCT, respectively in Naples and Salerno), the management companies of the Campania-based operational interports (Interporto Campano and Interporto Sud Europa, respectively in Nola and Marcianise interport) and their intermodal terminals (the subsidiaries TIN and NAOS, respectively in Nola and Marcianise interport), the major Italian rail freight companies (Trenitalia and Rail Traction Company), and other Campania region-located operators (FERPORT Napoli, Logship, Italcontainer, DHL Global Forwarding Italy, Schenker, Omnialogistica, De Crescenzo, and Sticcosped).

the capacity and costs of transport services among nodes. Our main interest lies with the solution traffic through the two interports at Nola and Marcianise (tab. 5).

It turns out that the 95% of the demand at Nola interport for full containers disembarked in Naples port is satisfied by road transportation (56,892 TEUs). The containers are cleared by customs in Naples and then transported by truck to Nola (merchant haulage). The remaining 5% of the demand at Nola for full containers disembarked in Naples is satisfied by hauling the containers by railway under customs bond from Naples to Marcianise interport (carrier haulage). Here the containers are cleared by customs and then transported to Nola by truck (3,000 TEUs). On the other hand, the whole demand at Marcianise interport for full containers arriving from Naples port (10,890 TEUs) is serviced by carrying the load units by railway under customs bond from Naples to Nola (carrier haulage). There the containers are cleared by customs and then transported to Marcianise by truck.

Table 5. Optimal inland flows of imported containers through Campania seaports and interports*

	Destinations…				
	NOL	***NCC***	***MAR***	***MCC***	***Other inland locations***
Leaving the port of Naples (NAP)					
Full TEUs cleared at the port and shipped by road (merchant haulage)	56,892				92,005
Full TEUs cleared at the port and shipped by railway (merchant haulage)					16,725
Full TEUs shipped by railway under customs bond (carrier haulage)		15,000		3,000	
Empty TEUs shipped by road	4,034		772		12,249
Empty TEUs shipped by railway					5,200
Leaving the port of Salerno (SAL)					
Full TEUs cleared at the port and shipped by road (merchant haulage)			302		68,735
Full TEUs cleared at the port and shipped by railway (merchant haulage)	1,493				1,095
Full TEUs shipped by railway under customs bond (carrier haulage)		56			
Empty TEUs shipped by road	149		199		94,762
Empty TEUs shipped by railway	951				1,405
Leaving the virtual interport node with customs function at Nola (NCC)					
Full TEUs from NAP cleared at the interport and shipped by road			10,890		655
Full TEUs from NAP cleared at the interport and shipped by railway					3,455
Full TEUs from SAL cleared at the interport and shipped by railway					56
Leaving the virtual interport node with customs function at Marcianise (MCC)					
Full TEUs from NAP cleared at the interport and shipped by road	3,000				
Leaving the virtual interport node without customs function at Nola (NOL)					
Empty TEUs from SAL and shipped from the interport by railway					58

* *NAP = port of Naples; SAL = port of Salerno; NOL = Nola interport (no customs function); NCC = Nola interport (customs function); MAR = Marcianise interport (no customs function); MCC = Marcianise interport (customs function)*

These results may in the first instance seem odd, but can be explained as it follows. The key bottlenecks in the system are the capacity constraints on railway shuttles between the port of Naples and the two interports. For the optimal solution, all available railway capacity from Naples to each of the two interports is utilized (see Table 6). Container carrier haulage by railway under customs bond dramatically reduces the generalized cost of the releasing operations at the seaport.

The railway services between Naples and Calabria-located destinations (Rosarno and San Ferdinando, which are the rail nodes of Gioia Tauro port, in Southern Italy) would also operate at the limit of their capacity. Railway-to-railway transhipment through Nola interport is advantageous for full containers imported by sea through Naples and demanded in Milan, Taranto and San Ferdinando. But railway connections from the interports to other national inland locations have low levels of capacity utilization. Such services are also employed for traffic not originating in the Campania seaports.

Table 6. Rail traffics of full and empty containers (observed and resulting from the model), rail capacity utilization (resulting from the model), and shadow values of the rail capacity constraints

Railway link	**Number of one-way weekly trains - model**	**Maximum number of TEUs/train - model**	**Maximum annual one-way capacity (TEUs) - model**	**One-way annual shipments in the last observed year (TEUs)**	**One-way annual shipments resulting from the model (TEUs)**	**Shadow value of the capacity constraint resulting from the model (Euros/TEU)**
Naples-Nola	5	60	15,000	6,707	15,000	203.9
Naples-Marcianise	1	60	3,000	481	3,000	234.1
Naples-Bari	5	50	12,500	6,054	9,408	0
Naples-Rosarno	3	50	7,500	2,408	7,500	169.8
Naples-San Ferdinando	1	50	2,500	2,410	2,500	187.5
Naples-Ancona	1	50	2,500	44	1,114	0
Naples-Foligno	1	50	2,500	30	1,272	0
Naples-Rubiera	1	50	2,500	129	131	0
Nola-Taranto	3	50	7,500	1,618	2,834	0
Nola-Rosarno	2	50	5,000	1,078	0	0
Nola-San Ferdinando	5	48	12,000	475	597	0
Nola-Foligno	1	50	2,500	51	0	0
Nola-Rubiera	1	50	2,500	66	0	0
Nola-Segrate Milan	5	12	3,000	750	138	0
Marcianise-Taranto	1	50	2,500	24	0	0
Marcianise-Rosarno	1	50	2,500	0	0	0
Marcianise-Civitavecchia	1	50	2,500	0	0	0
Salerno-Nola	1	50	2,500	395	2,500	43.2
Salerno-Bari	1	50	2,500	2,081	2,500	36.1

The results clearly demonstrate the economic and social advantages that would accrue in an extended gateway system based on a fully operational customs status at both Campania interports[29]. The model measures the benefits of a regime of customs continuity between seaports and interports. Such a system would be advantageous even for distributing containerized cargoes arriving at the port of Naples and destined to the two interports themselves. For the logistic agent, given the very high generalized unit port cost at Naples, it would at all times be preferable a container distribution solution based on the carrier haulage by

[29] In the current application of the *interport model*, the objective function does not include transport externality costs, but it is clear that transportation by railway adds to social welfare.

railway under customs bond from the port toward a regional interport, and therefore both on the customs clearance at the interport and the final transportation by truck towards the other interport. There is a huge potential for operational integration between the two different regional interport sites. This provides an indication of possible industrial, infrastructure and organizational policies that could be pursued by public and private parties.

Next, turning to containers disembarked in the port of Salerno, the situation is different. In Salerno there is not the same customs-induced port congestion as in Naples. Salerno is a typical export port (the import traffic being dominated by empty containers and the export traffic dominated by full containers). In particular, imports arriving from China are low - a situation quite different from that at the port of Naples. Direct and indirect costs incurred at Salerno are also lower than at Naples.

Nevertheless, the railway capacity between the port of Salerno and the inland nodes of Nola and Bari would be fully utilized. The connection to Nola would be employed mainly for transporting full containers already cleared in the port (1,493 TEUs). These containers contribute to the utilization of about 60% of the potential port-interport railway capacity, while a share of 38% would instead be devoted to the re-positioning of empty containers (951 TEUs). The remaining 2% would consist of containers transported by railway under customs bond and on behalf of shipping lines from Salerno to Nola and destined to the Lombardia market. Once released by customs at Nola, they would be sent by railway from Nola to the Segrate Milan terminal (56 TEUs).

Expansion of the customs facilities for the inland container traffic throughout the Campania logistic system, backed up by an efficient railway system, would clearly be an effective means for expanding the commercial and geographical hinterland of the regional seaport system. It would boost the competitiveness of all the first-tier seaport and interport nodes in the region. This holds true also for cargoes destined to Northern Italy and, more generally, to Central and Northern Europe.

Table 6 lists both observed data and solution values on rail shipments from Campania seaports and interports (respectively, in the fifth and sixth column). The observed data referring to the traffics towards Nola and Marcianise include possible transits from Campania seaports towards other inland final destinations. Instead, the observed traffics from Nola and Marcianise include containers (full and empties) which were not disembarked in the Campania seaports. The solution figures exclusively refer to containers (full and empties) disembarked at the seaports, including transits towards other inland final destinations. The table also exhibits the modelled capacity limits on the various railway links and the solution shadow prices of such capacity constraints (respectively, in the fourth and seventh column).

The shadow prices of the railway capacity constraints indicate the imputed value of the objective function arising from an improvement of infrastructure and/or services. They confirm the importance of the off-dock logistic system. In particular, an increase of the railway capacity over the Naples-Nola, Naples-Marcianise, Naples-Rosarno, Naples-San Ferdinando, Salerno-Nola, and Salerno-Bari routes would generate logistic benefits. For instance, the total logistic cost reduction due to a unit relaxation of the capacity constraint on the railway link from Naples to Marcianise equals to 234 euros.

The solution values of the *interport model* confirm the current critical situation of the Marcianise interport as it regards the inland distribution of maritime containers. In particular, it is surveyed a demand deficit and the consequent under-utilization of the intermodal capacity at Marcianise. The model hypothesizes a fully operational Marcianise-based extended gateway system from Naples, which paradoxically does not correspond to the real operational situation yet. Definitively, Marcianise presents an enormous potential for improving both its off-dock function and railway connections for the inland distribution of the maritime containers handled in the seaport of Naples. A slightly different situation features instead the interport of Nola, whose capacity is more utilized.

Sensitivity tests. In Figures 6 and 7 the results of some sensitivity tests are reported. We calculated the change of both the optimal value of the objective function and the total generalized average unit port cost that would arise under some alternative values of the parameter measuring the average unit dwell time of full containers cleared by customs at the port of Naples. Compared with the base case, the dwell time variations taken into consideration are: (i) a 50% reduction of the base case dwell time; (ii) a 25% reduction of the base case dwell time; (iii) a 25% increase of the base case dwell time; (iv) a 50% increase of the base case dwell time. As the figures illustrate, a less than proportional change of the optimal value of the objective function occurs, and an almost proportional change of the total generalized average unit port cost.

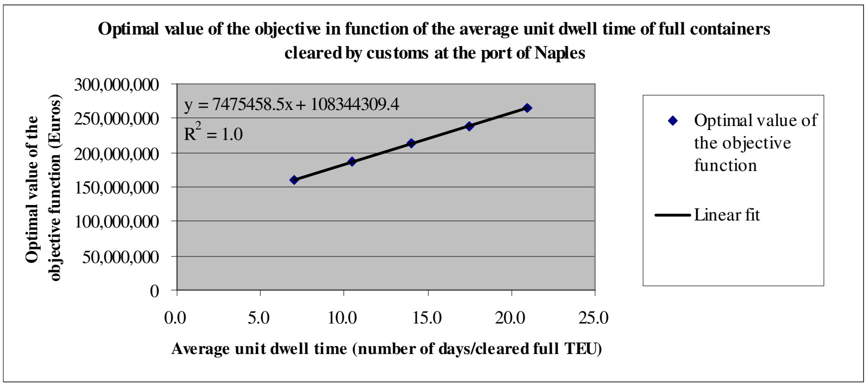

Figure 6. Optimal value of the objective in function of the average unit dwell time of full containers cleared by customs at the port of Naples

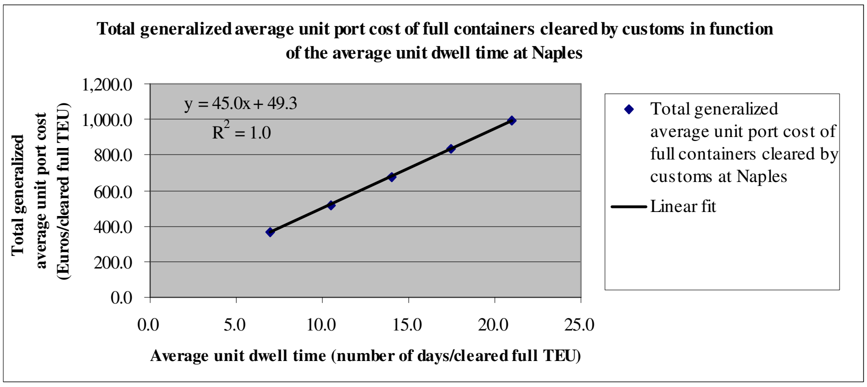

Figure 7. Total generalized average unit port cost of full containers cleared by customs in function of the average unit dwell time at Naples

Finally, Table 7 reports the results of sensitivity tests calculating the change of the objective function, as well as that of both the rail share of total inland traffic outgoing the port of Naples, and the rail traffic under customs bond and on behalf of shipping lines (carrier haulage) between Naples port and the interports of Nola and Marcianise, that would occur under some alternative values of the parameter measuring the railway capacity over seaport-interport links. The capacity variations considered were the following: (i) 100% increase of the base case ("ONE"); (ii) 200% increase of the base case ("TWO").

Table 7. Sensitivity results under alternative assumptions of railway capacity between Naples port and the regional interports

	BASE case	***ONE***	***TWO***
No. of one-way weekly trains over the Naples-Nola link	5	10	15
Yearly capacity of the Naples-Nola one-way rail link (TEUs)	15,000	30,000	45,000
No. of one-way weekly trains over the Naples-Marcianise link	1	2	3
Yearly capacity of the Naples-Marcianise one-way rail link (TEUs)	3,000	6,000	9,000
Share of the rail traffic on the total inland traffic from Naples	19%	28%	36%
Optimal value of the objective function (million Euros)	212.9	209.2	205.8
Rail traffic under customs bond between Naples and the interports (TEUs)	18,000	36,000	54,000
Utilization rate of the rail links between Naples and the interports	100%	100%	100%

The results demonstrate that even under the hypothetical scenario of a dramatic improvement of the railway capacity between the ports and the interports, such increased capacity would still be fully utilized. Shippers would still find it advantageous to relocate customs clearance procedures from the seaports to the interports.

6. Conclusions

The future expansion of the Campania container distribution system depends crucially on an improved supply of interport services (at Nola, Marcianise, and Battipaglia, the latter being under construction). New types of freight infrastructures and logistic poles (e.g. distriparks) in the Campania region do not seem imminent.

The numerical results of the *inward interport model* confirm the importance of the regional off-dock and inland logistic system, i.e. of the Campania interports, for the inland distribution of international maritime containers disembarked in the Campania seaport cluster. They reveal some of the current deficiencies of the Campania regional load center network in terms of seaport-interport connections. It also suggests possible policies that would further a better integration between seaports and interports.

The case study highlights the benefits of modern customs and intermodal procedures for inland container logistics, which are currently adopted only in few cases in Campania. The model admits the possibility to employ both the Campania operational interports, that is Nola and Marcianise, as extended gates of the regional seaport system. Therefore, direct and indirect costs for container releasing at the seaports can be reduced. Such kind of interport-related economic and logistic benefits deserves particular attention.

The results demonstrate that it is possible to improve the competitiveness of railway services over short distances (Naples-Nola and Naples-Marcianise) only by adopting an extended gateway system based both on the possibility of carrier haulage by railway under customs bond over seaport-interport routes, and customs clearance at the interports. By both an adequate regulation (i.e. granting to Marcianise intermodal terminal a fully operational customs bonded status) and an efficacious organizational system (i.e. extending the possibility of carrier haulage under customs bond also to the Naples-Marcianise railway link), the current railway capacity and beyond can be fully employed over port-interport connections.

The numerical solution also indicates that the choice of one regional interport or the other for containers disembarked in the port of Naples may be immaterial in terms of costs. Shippers may even consider the carrier haulage by railway under customs bond from Naples toward one interport (Nola or Marcianise) and the subsequent transport by road towards the other one. This indicates a possible integration of the use of the two regional interports.

The hypothesized customs facilitations between seaports and interports could prove to be an useful tool to both expand the Campania container seaports' hinterland and guarantee, through an efficient railway system, the competitiveness of the regional load center network system also for cargoes destined to Northern Italy and more generally to Central and Northern Europe.

Many inefficiencies could easily be corrected. These include the current suspension of railway connections from the port of Salerno, the absence of a customs bonded area and X-ray scanner equipment at the Marcianise interport, and the low rates of utilization of the existing container railway capacity of the whole Campania regional load center network system. Limited customs facilities at the port of Naples create severe congestion of containers; this leads to high unit dwell times and excessive generalized port costs.

Some of these shortcomings were recently discussed by the managing director of Co.Na.Te.Co. Criticizing the Campania regional logistics public policy, he voiced the opinion that local policy makers have failed to integrate the operations between seaports and interports. In his view, the Marcianise interport rather than Nola should become the first off-dock node for containers handled at the port of Naples (Scorza, 2009).

The model formulation and the numerical application proposed are also featured by some limits however constituting a potentiality in terms of development opportunities concerning future extensions. For example, time-related container leasing costs and/or safety stock costs can be included among the parameters of the model.

The model can also feature the external costs of transport operations, and the possibility of value enhancement of the goods at the interports through semi-manufacturing logistic services (opening containers and repacking goods together with marketing material, for instance). In this case, the optimization problem will consist of maximizing the value of all "upgraded" containers processed at the interports, calculated net of the internal and external logistic costs throughout the entire network, and subject both to balance conditions at all nodes and capacity constraints.

Future applications of the *interport model* will take simultaneously into consideration the inland logistics of both import and export containerized trades through the Campania regional load center network *(inward-outward simultaneous interport model*). Finally, the model can be extended for investigating wider territorial logistic systems.

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