A MODEL OPTIMIZING THE PRIVATE AND SOCIAL COST-EFFICIENCY OF PORT-HINTERLAND CONTAINER LOGISTICS

Fedele Iannone
Institute for Service Industry Research (IRAT) - National Research Council (CNR), Naples, Italy

1. INTRODUCTION

In any sector there cannot be economic efficiency unless the prices reflect all costs to the society actually caused by the economic agents. Sustainable or "green" freight logistics systems are concerned with the movement of goods, taking account of the environmental and social impacts of operations. Thus the objectives are not only concerned with private aspects, such as profit maximization, but also with the wider effects of logistics on social well-being, particularly in terms of the negative externalities - also referred to as "external costs" - associated with congestion, accidents, climate change, pollution, and other biological and ecosystem damages that derive from transport operations and are not normally taken into account in the decisions made by the users of transport systems. The challenge lies in minimizing these impacts while offering strong logistic benefits. These developments are particularly in the focus of modern sector policies geared towards facilitating intermodality and enabling efficient supply chains (EC, 2001, 2007, 2011). In addition, some private companies are starting to adopt sustainable approaches to supply chain management and logistics as part of their Corporate Social Responsibility (CSR) agenda (see for instance: Sarkis, 2006).

A number of specific policy measures can address sustainability problems in freight logistics, such as the pricing of transport external costs by means of taxes, tolls and modal shift grants. According to the "full costing" or "social marginal cost charging" approach, transport prices must correspond to the additional short-term cost created by one extra user of the infrastructure. This additional cost should include the costs to the user and the external costs. The sum of private and external costs gives the social cost of transport (EC, 2008). The *full cost pricing* can alter the relative competitiveness of different transport modes in favor of alternative logistic chain structures and more environmentally and socially friendly ways of organizing and managing the freight flows.

Only recently, the incorporation of the negative external impacts of transportation into the analysis and planning of supply chain operations and intermodal freight logistics systems has become an important research topic among scholars and one of the evolving areas of interest to practitioners (Anciaux and Yuan, 2007; Bauer et al., 2010; Cetinkaya et al., 2011; Feng and Huang, 2005; GCI, 2008; Janic, 2007; Lee et al., 2010; Liao et al., 2010; Macharis et al., 2010; Mallidis et al., 2010; McKinnon et al., 2010; Paksoy et al., 2010; Pan et al., 2010; Wang et al., 2011). This paper intends to contribute to the literature by analyzing a sustainable port-hinterland container logistics problem. In particular, a capacitated multimodal and multicommodity network programming model, called "interport model", has been employed to investigate the inland distribution of import/export containers handled at the seaports of Naples and Salerno located in the Campania region of Southern Italy. The loading units can transit through the regional dry port facilities located at Nola and Marcianise (the so called “interports”), as well as through extra-regional locations with railway terminal, before reaching their destination.

An increasing number of studies have theoretically addressed the new role of port-hinterland container connections in trade logistics, with consequent economic, environmental and social dimensions (see for instance: OECD-ITF, 2009; UNECE, 2010). Optimization of port-hinterland logistics is crucial to meet increasing container traffic demand and sustainable development. Inefficient hinterland connections undermine the competitiveness both of seaports and of the wider regional logistics and productive systems the seaports belong to, while leading to increased internal and external costs of supply chains.

The *interport model* takes into account all the container-related social generalized logistic costs throughout the entire port-hinterland multimodal network. This analytic tool allows measuring the logistic and socio-economic benefits arising both from shifting the seaport exit/entry of containers to the regional interports (the “extended gateway” concept[1]), and from employing intermodal solutions for inland distribution. It can simulate long-term alternative scenarios in terms of supply of infrastructures and services, demand characteristics, and government and industrial policies. For instance, the evaluations allowed by the model can help to define grant policies supporting innovative inland transport solutions aimed at improving the competitiveness and sustainability of the regional container logistics system.

In the present work, two empirical applications of the *interport model* have been formulated and solved, one internalizing in the objective function also the external costs of inland transport (in terms of climate change, air pollution, noise, accidents and congestion), and the other one which does not take account of externalities. The solutions of these modeling applications have been compared with the real-life scenario. All different scenarios have been also compared in terms of physical air emissions from transport. Finally, some sensitivity tests have been executed. In this manner, it has been possible to make a comprehensive and detailed assessment of the potential to improve the current performances of the Campanian seaport-interport logistics system. The attained results can constitute a useful knowledge base for regional policy initiatives aimed at promoting intermodal logistics solutions addressing modal rebalance and the pursuit of social welfare.

The paper proceeds as follows. Section 2 contains both a methodological description of the model and a stylized formulation of its objective function. Section 3 illustrates the main features and results of the empirical applications of the model; the results obtained in the different modeling scenarios are also compared with the observed real situation. Section 4 addresses conclusions and presents future research perspectives.

2. METHODOLOGY

2.1. General description of the interport model

The *interport model* is a large scale and inventory-theoretic transhipment model which identifies possible optimal choices concerning the inland logistics of maritime containers transiting through a distribution network encompassing seaports, interports and other locations. The model is multimodal, allowing for both road and rail transportation, and multicommodity, covering both full and empty containers.

As presented here, the model is a novel extension of the homonymous model developed by Iannone (2010) and Iannone and Thore (2010), as the objective function also internalizes the external costs in terms of greenhouse gas emissions, air pollution, noise, accidents and congestion deriving from inland transport operations.

The programming problem minimizes the total social generalized logistic cost of container distribution throughout the entire port-hinterland network. The total cost includes internal and external transportation costs, in-transit inventory holding costs, container leasing costs, terminal operation costs, and customs control costs. The optimization is subjected to flow conservation constraints at all nodes, non-negativity constraints on endogenous variables, and capacity constraints over all railway links. In addition, the *interport model* also features a road supply sub-model for the quantification of road transport times at national scale according to the Road Code regulations.

The problem is linear in both the objective function and the constraints, and it is made up by two main components or sub-problems. A first component optimizes the inland flows of imported containers, while the second one optimizes the inland flows of exporting containers. The program simultaneously optimizes the *import* and *export* sub-models. It solves for the optimal port-hinterland routing of containers. This task includes finding the detailed quantities of full and empty loading units to be shipped from/to seaports, the transportation modal choice along each inland link, and the detailed pathway through the system chosen, including container transhipments at regional interports and at other intermediate inland nodes with railway terminal. The model also determines whether shippers will choose to have their consignments controlled and cleared by customs directly at the seaports, or whether they will prefer to comply with customs formalities at the interports.

In particular, by means of parameters representing dwell times, free of charge storage times, handling charges, demurrage charges and probabilities of customs controls, the *interport model* simulates in detail the container releasing operations and their related pricing mechanisms at seaport and interport terminals, including the possibility of relocating storage and customs operations from the seaports to the interports (i.e. the *extended gateway* concept). In this respect, the model allows for spelling out various arrangements of customs checks on full containers (automated computerized controls, documentary control, X-ray scanning controls, and physical inspections).

The equilibrium solution of the model can be broken down into merchant flows and carrier flows, representing in any case the optimum of a hypothetical shipper operating the entire network. In the common fashion, the overall solution for this economic agent can be shown to coincide with the decentralized solutions of individual programs for each participating logistic agent in the network.

Furthermore, at the moment, the *interport model* is a static and deterministic problem. All model's elements, from container demands to decision variables, cost structure and capacity constraints are for one planning period (which in the empirical applications has corresponded to an operational year), and are assumed not to vary during the planning horizon.

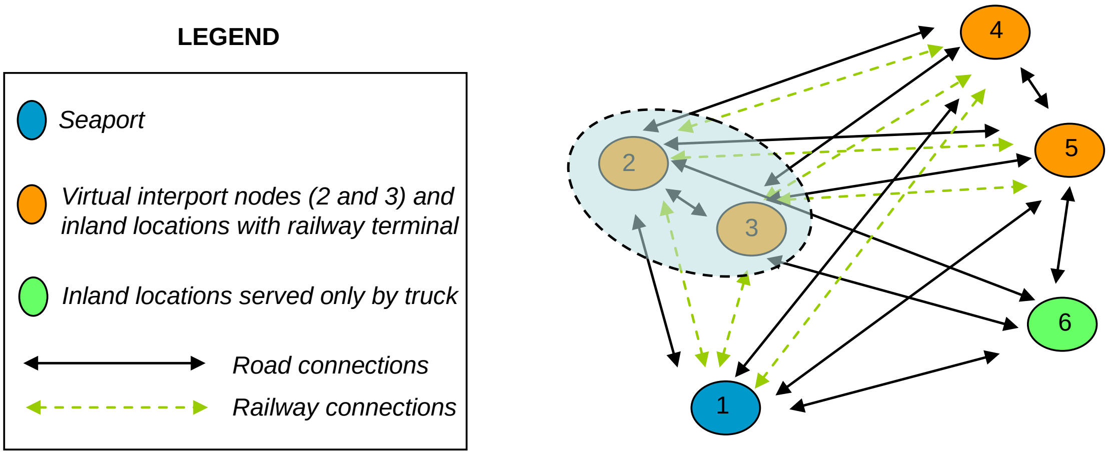
Finally, each interport infrastructure is modelled through a pair of "virtual" nodes having an identical geographical location but involving in part different interport processing activities. The splitting of a single interport facility into two separate nodes can be seen as a mathematical artefact of graphic theory. It enables the formulation of a standard linear programming model for the entire network, thus avoiding explicit 0-1 programming features to handle the decisions of where to carry out the customs clearance and storage operations.

2.2. Stylized formulation of the model's objective function

This sub-section provides a stylized formulation of the *interport model*'s objective function. Such example covers all the features of the objective function of the larger numerical applications presented in this paper.

Figure 1 firstly shows a first tier regional node infrastructure system for container traffic. This system encompasses a single seaport represented by node *1* and a single interport featuring the two virtual nodes *2* and *3*. Node *2* has intermodal and logistic warehousing functions, while node *3* has intermodal and customs functions. Finally, there are three other inland locations, that is the nodes *4*, *5*, *6*, of which only *4* and *5* have a railway terminal.

Figure 1: Stylized model of multimodal inland logistic network with virtual interport nodes



The seaport node *1* is the origin node in the *inward* or *import* sub-model and the destination node in the *outward* or *export* sub-model. Nodes *2*, *4*, *5* and *6* are destination nodes in the *inward* sub-model and origin nodes in the *outward* sub-model. Furthermore, nodes *2*, *4* and *5* are also intermediate multimodal transhipment nodes both over the *inward* and *outward* inland direction. Node *3* is a pure intermediate multimodal transhipment node because it does not have a local demand and/or supply of containers.

As for the two-way railway links represented in the figure, the seaport node *1* is connected to the node *4* and to the nodes *2* and *3*. Node *3* is reachable from the seaport node only by railway carrier haulage and exclusively for the forwarding of customs bonded full containers[2]. Nodes *2* and *3* are also linked to the nodes *4* and *5*. Therefore, each railway service from/to the interport includes the connections from/to each of the two corresponding virtual nodes.

As for the two-way road links, node *1* is connected to all the other nodes of the network, excluding the virtual node *3*. Both virtual nodes *2* and *3* are linked by road to all the other inland locations of the network; furthermore, road transport at a zero generalized cost is admitted between the two virtual nodes to meet the container demand/supply of importing/exporting operators located in the interport. Finally, the other inland nodes having a railway terminal are connected by road to some inland locations which are directly linked by road with regional port and interport nodes. In particular, node *4* can also be employed as intermediate node to serve node *5* by truck, while node *5* can also be employed as intermediate node to serve nodes *4* and *6* by truck.

The notations employed in the objective function of the model are shown below.

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

$L\ (I)$: set of all intermodal nodes of the regional logistic system = $\{1,\ 2, 3\}$

$N\ (L)$: set of intermodal nodes of the regional logistic system excluding virtual interport nodes with customs function = $\{1,\ 2\}$

$O\ (L)$: set of intermodal nodes of the regional logistic system excluding virtual interport nodes without customs function = $\{1,\ 3\}$

$P\ (O)$: set of seaport nodes of the regional logistic system = $\{1\}$

$Q\ (N)$: set of virtual interport nodes without customs function = $\{2\}$

$D\ (O)$: set of virtual interport nodes with customs function = $\{3\}$

$Z\ (I)$: set of all inland locations demanding/offering containers imported/to be exported = $\{2, 4, 5, 6\}$

$E\ (Z)$: set of inland locations (excluding interports) demanding/offering containers imported/to be exported = $\{4, 5, 6\}$

$R\ (Z)$: set of inland locations without rail terminal and demanding/offering containers imported/to be exported = $\{6\}$

T: set of container types = $\{full, empty\}$

M: set of admitted inland transportation modes = $\{rail, truck\}$

Flow_Type: set of direction types for inland container flows = $\{import, export\}$

$\left[c^{tijm}_{flow\_type}\right]$: row vector of total generalized unit costs (in Euros/TEU) for transport of containers of type $t \in T$ by mode $m \in M$ between nodes $i \in I$ and $j \in I$ over direction $flow\_type \in Flow\_Type$

$\left[Tot\_extern\_cost^{tijm}_{flow\_type}\right]$: row vector of total external unit costs (in Euros/TEU) for transport of containers of type $t \in T$ by mode $m \in M$ between nodes $i \in I$ and $j \in I$ over direction $flow\_type \in Flow\_Type$

$\left[f^{n}_{flow\_type}\right]$: row vector of total generalized unit costs (in Euros/TEU) of releasing operations for empty containers at intermodal node $n \in N$ over direction $flow\_type \in Flow\_Type$

$\left[g^{pm}_{flow\_type}\right]$: row vector of weighted average total generalized unit port costs (in Euros/TEU) of the releasing operations for full containers cleared/to be cleared by customs at seaport node $p \in P$ and leaving/entering the same node by transport mode $m \in M$ over the direction *import/export*

$\left[k^{p}_{flow\_type}\right]$: row vector of total generalized unit port costs (in Euros/TEU) of the releasing operations for full containers leaving/entering seaport node $p \in P$ by railway under customs bond on behalf of shipping lines (and without any accompanying inland transit document) towards/from virtual interport nodes with customs functions over the direction *import/export*

$\left[s^{qm}_{flow\_type}\right]$: row vector of total generalized unit interport costs (in Euros/TEU) of the releasing operations for full containers already cleared/yet to be cleared in seaport node $(p \in P)$ and leaving/entering the virtual interport node $q \in Q$ by transport mode $m \in M$ over the direction *import/export*

$\left[u^{pdm}_{flow\_type}\right]$: row vector of weighted average total generalized unit interport costs (in Euros/TEU) over the direction *import/export* for releasing operations concerning full containers arriving in/leaving from virtual interport node $d \in D$ from/towards seaport node $p \in P$ by railway under customs bond on behalf of shipping lines (without any accompanying inland transit document), and subsequently/previously leaving/entering the same virtual interport node by transport mode $m \in M$ after/before customs clearance

$\left[x^{m}_{tpzij}\right]$: column vector of inland shipments (measured in TEUs) over the direction $import \in Flow\_Type$ for containers of type $t \in T$ disembarked at seaport $p \in P$, destined to inland location $z \in Z$ and forwarded between nodes $i \in I$ and $j \in I$ by transport mode $m \in M$

$\left[y^{m}_{tzpij}\right]$: column vector of inland shipments (measured in TEUs) over the direction $export \in Flow\_Type$ for containers of type $t \in T$ originating from inland location $z \in Z$, to be embarked at seaport node $p \in P$ and forwarded between nodes $i \in I$ and $j \in I$ by transport mode $m \in M$

The stylized objective function of the *import/export simultaneous interport problem* incorporating transport external costs is:

Min $W =$

$$
\begin{aligned}
&= \sum_{t\in T}\sum_{p\in P}\sum_{z\in Z}\sum_{i\in I}\sum_{j\in I}\sum_{m\in M}\left\{\begin{array}{l}\left[\left[\begin{pmatrix} c^{tijm}_{import\in Flow\_Type} + \\ +Tot\_extern\_cost^{tijm}_{import\in Flow\_Type}\end{pmatrix}\cdot x^{m}_{tpzij}\right]+\right.\\ \left.\left[\begin{pmatrix} c^{tijm}_{export\in Flow\_Type} + \\ +Tot\_extern\_cost^{tijm}_{export\in Flow\_Type}\end{pmatrix}\cdot y^{m}_{tzpij}\right]\right]\end{array}\right\}+ \\
&+\sum_{p\in P}\sum_{z\in Z}\sum_{n\in N}\sum_{i\in I}\sum_{m\in M}\begin{bmatrix}\left(f^{n}_{import\in Flow\_Type}\cdot x^{m}_{empty\in T,\,pzni}\right)+\\ +\left(f^{n}_{export\in Flow\_Type}\cdot y^{m}_{empty\in T,\,zpni}\right)\end{bmatrix}+ \\
&+\sum_{p\in P}\sum_{z\in Z}\sum_{w\in Z}\sum_{m\in M}\begin{bmatrix}\left(g^{pm}_{import\in Flow\_Type}\cdot x^{m}_{full\in T,\,pzpw}\right)+\\ +\left(g^{pm}_{export\in Flow\_Type}\cdot y^{m}_{full\in T,\,zpwp}\right)\end{bmatrix}+ \\
&+\sum_{p\in P}\sum_{z\in Z}\sum_{d\in D}\begin{bmatrix}\left(k^{p}_{import\in Flow\_Type}\cdot x^{rail\in M}_{full\in T,\,pzpd}\right)+\\ +\left(k^{p}_{export\in Flow\_Type}\cdot y^{rail\in M}_{full\in T,\,zpdp}\right)\end{bmatrix}+ \\
&+\sum_{p\in P}\sum_{z\in Z}\sum_{q\in Q}\sum_{e\in E}\sum_{m\in M}\begin{bmatrix}\left(s^{qm}_{import\in Flow\_Type}\cdot x^{m}_{full\in T,\,pzqe}\right)+\\ +\left(s^{qm}_{export\in Flow\_Type}\cdot y^{m}_{full\in T,\,zpeq}\right)\end{bmatrix}+ \\
&+\sum_{p\in P}\sum_{z\in Z}\sum_{d\in D}\left\{\begin{array}{l}\sum_{w\in Z}\begin{bmatrix}\left(u^{pd,truck\in M}_{import\in Flow\_Type}\cdot x^{truck\in M}_{full\in T,\,pzdw}\right)+\\ +\left(u^{pd,truck\in M}_{export\in Flow\_Type}\cdot y^{truck\in M}_{full\in T,\,zpwd}\right)\end{bmatrix}+\\ +\sum_{e\in E}\begin{bmatrix}\left(u^{pd,rail\in M}_{import\in Flow\_Type}\cdot x^{rail\in M}_{full\in T,\,pzde}\right)+\\ +\left(u^{pd,rail\in M}_{export\in Flow\_Type}\cdot y^{rail\in M}_{full\in T,\,zped}\right)\end{bmatrix}\end{array}\right\}
\end{aligned}
\tag{1}
$$

The objective function (1) denotes the total social generalized logistic cost for the distribution of imported and exporting full and empty containers throughout the port-hinterland network. The first term represents the total social cost for rail and road transportation of full and empty containers over the network. The second term indicates the total releasing cost for empty containers at seaport and interport nodes. The third term denotes the total releasing cost for imported and exporting full containers cleared and to be cleared by customs at the seaport and leaving and entering by road and railway. The fourth term indicates the total releasing cost for imported and exporting full containers leaving and entering the seaport by railway under customs bond on behalf of shipping lines and without any accompanying inland transit document. The leaving containers will be customs cleared at the interports. On the contrary, arriving containers have been already cleared at the interports. The fifth term of the function is the total releasing cost for imported and exporting full containers already cleared and to be cleared in the seaport, entering and leaving the interports, and leaving and entering the same interports by road and railway. Finally, the sixth term represents the total releasing cost for imported and exporting full containers cleared and to be cleared by customs at the interports, and leaving and entering the same interports by road and railway.

The sets Q and D introduce the so called "virtual interport nodes", which have the same geographical location but offer different services. For instance, over the *import* direction, a full container disembarked 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 node 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 virtual node $d \in D$ having customs function. In this way, the shipper may avoid costly delays at seaport nodes awaiting access to customs clearance. Of course, the process is reversed for export flows over the *outward* direction. Empty containers do not require customs clearance before being released from intermodal nodes.

The critical direct and indirect internal cost items explicitly taken into account by the model are:

- container handling costs;
- container storage costs, in function both of the demurrage charge and of the dwell time exceeding the free time provided by terminal companies at seaports and interports;
- additional direct costs for physical inspection and X-ray scanner control by customs at seaports and interports;
- in-transit inventory holding costs, in function of the customs declared value of cargoes, the time duration of distribution operations, and a reference interest rate reflecting both the opportunity cost of the capital tied in containerized goods and the economic-technical depreciation costs of the same goods;
- container leasing costs, in function both of a container leasing charge and of the time duration of distribution operations;
- transport costs.

In the objective function (1) such cost items are compressed into aggregated parameters (c, f, g, k, s, u). Furthermore, the costs of transport either by road or railway toward/from generic nodes over the *import/export* direction include the terminal operation costs related to the offloading/loading of the container from/on the vehicle at the end/beginning of the trip. The costs of road transport between the inland nodes featuring a railway terminal (excluding the interport nodes) and the other inland nodes comprise the costs of terminal operations both at the departure and at the arrival.

Total travel times by road over admitted links are equal to the driving time both on motorways and other road types plus the time for rests and stops prescribed by Road regulations under the "1 driver on board" hypothesis. Road driving times are computed by assuming two different admitted truck's average speeds over motorways and other road types. The number and time duration of rests and stops to be observed in a transportation by truck are calculated in function of the driving time. As for total travel times by rail over admitted links, these are instead exogenous.

The external transport costs included in the model are:

- climate change;
- air pollution;
- noise;
- accidents;
- congestion.

In the objective function (1) such costs are incorporated into the aggregated parameter Tot_extern_cost.

The weighted average total generalized unit port and interport costs of releasing operations both for cleared and clearing full containers (that is the parameters g and u) are computed by taking into consideration both direct costs and time-related indirect costs, according to the different probabilities observed in the seaport p for the different types of customs control on import and export flows.

3. ANALYSIS

3.1. General features of the empirical applications

Two empirical applications of the model to the container logistics system of the Campania region in South of Italy[3] have been executed based on real industry data[4]. The first application does not take into account transport external costs and minimizes an internal total generalized logistic cost of port-hinterland distribution. The other application features the internalization of transport externalities in the objective function; therefore, in this case the model minimizes a social total generalized logistic cost. The empirical results in terms of logistic flows, internal costs and external costs deriving from such applications have been compared with the observed real situation in 2007. The different scenarios have been also compared in terms of physical atmospheric emissions arising from inland transport operations. Finally, some post optimality tests have been executed.

The real port-hinterland container network under consideration features 24 nodes and 163 road and rail links. It consists of the following seaports, interports and other inland locations in Italy:

- *Seaports*: Naples and Salerno.
- *Interports*: Nola and Marcianise.
- *Inland locations accessible both by road and by rail*: Bari city/rail terminal; Taranto city/rail terminal, San Ferdinando city/rail terminal, Rosarno city/rail terminal, Lazio region/Civitavecchia rail terminal, Abruzzo and Marche region/Ancona rail terminal, Umbria region/Foligno rail terminal, Emilia Romagna region/Rubiera rail terminal, Lombardia region/Segrate Milan rail terminal.

- *Inland locations accessible by road only*: Naples province, Salerno province, Caserta province, Avellino province, Benevento province, remaining part of Puglia region, Basilicata region, remaining part of Calabria region, Sicily region, Tuscany region, Veneto region.

A fully operational customs status of the interports of Nola and Marcianise has been simulated in both applications. Furthermore, it has also been assumed the availability of railway connections at the Salerno port and, more generally, the availability of the container railway connections operated at the Campanian logistic system during 2005-2007.

Ultimately, each empirical model features 26 nodes and 219 admitted two-way road and rail links (including two virtual nodes at each regional interport and their related connections), 18,071 unknowns and 1,859 constraints. The models have been programmed and solved with the *GAMS* (*General Algebraic Modeling System*) computer language, using the solver *CPLEX*.

The external cost and air emission parameters employed in the analysis of real-life and modelled scenarios (Tabb. 1-2) have been estimated using specific figures released by the “Amici della Terra” association in collaboration with the Italian State Railway Company (AdT and FS, 2005). An average weight of containerized goods equalling 14 tonnes/TEU and a container tare of 2.3 tonnes/TEU have been assumed for the computations. Figure 2 demonstrates the rail-road differential in terms of total external cost of container transport for different inland distance classes. Clearly, the longer the distance, the greater will be the saving for any given transport volume.

Table 1: Marginal external costs of container transport in Italy (Euros/TEU-km)

	Road transport		**Rail transport**	
	Full containers	**Empty containers**	**Full containers**	**Empty containers**
Greenhouse gases	0.037	0.005	0.012	0.0017
Air pollution	0.142	0.020	0.020	0.0029
Noise	0.108	0.015	0.067	0.0095
Accidents	0.021	0.003	0.002	0.0002
Congestion	0.264	0.037	0.000	0.0000
Total	**0.572**	**0.081**	**0.101**	**0.014**

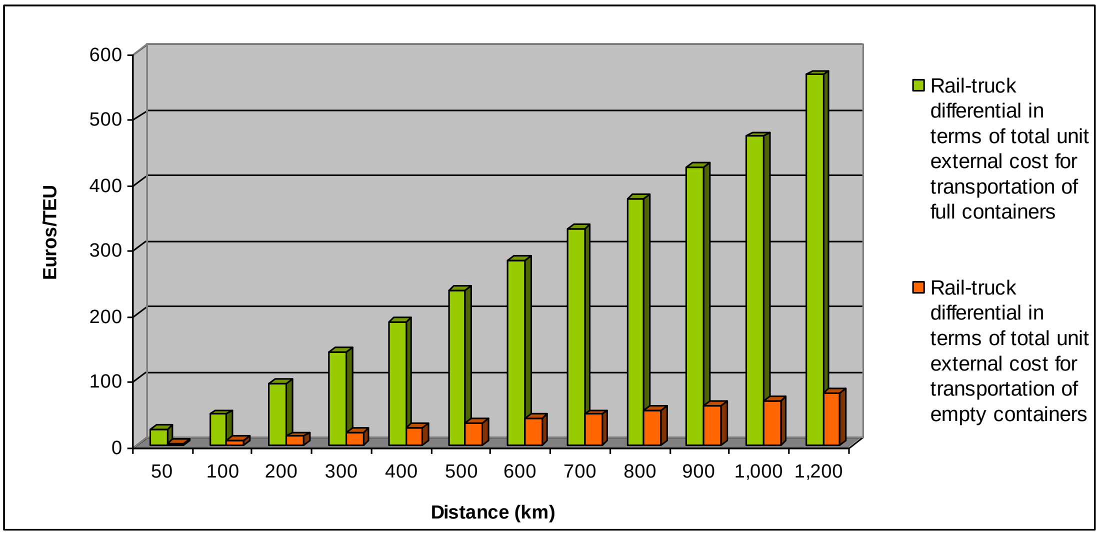
3.2. Main results

Table 3 compares the railway transport’s shares on the annual inland traffic of containers imported and to be exported through the seaports of Naples and Salerno in real-life and modelled scenarios. Table 4 compares the annual rail traffic volumes from/to the interports of Nola and Marcianise for import/export containers handled at the regional seaport cluster in the different cases of analysis. Table 4 also shows the rail transport’s shares on the total annual inland traffic of import/export containers leaving/entering the interports. Table 5 lists the internal, external and social total logistic cost items in the different scenarios. In Table 6 the scenarios are compared in terms of physical emissions of greenhouse gases and air pollutants from transport.

Table 2: Marginal physical air emissions of container transport in Italy (Tonnes/TEU-km)

	Road transport		Rail transport	
	Full containers	**Empty containers**	**Full containers**	**Empty containers**
CO_2	0.00182560	0.00025760	0.00059006	0.00008326
$CO_2 + CH_4 + N_2O$	0.00185519	0.00026178	0.00060729	0.00008569
SO_2	0.00000033	0.00000005	0.00000072	0.00000010
NO_x	0.00001528	0.00000216	0.00000158	0.00000022
PM_{10}	0.00000094	0.00000013	0.00000012	0.00000002
CO	0.00000470	0.00000066	0.00000050	0.00000007
COVNM	0.00000232	0.00000033	0.00000020	0.00000003
Total greenhouse gases	**0.00185519**	**0.00026178**	**0.00060729**	**0.00008569**
Total air pollutants	**0.00002357**	**0.00000333**	**0.00000312**	**0.00000044**

Figure 2: Marginal external benefits from modal shift in container transport in Italy as a function of distance (Euros/TEU)



It is worth pointing out that the modelled scenarios features greater rail transport volumes compared with the real situation. Of course, the scenario internalizing the externalities in the objective function presents the greatest rail flows.

The lower incidence of rail transport on total two-way inland traffic between seaports and interports characterizing the scenario with externalities compared with the other modelled scenario (Tab. 3) is determined both by the capacity saturation on the seaport-interport rail connections and by the fact that this scenario features the greater two-way road flows between seaports and interports. These are flows of loading units that are essentially destined to and originated at the same interports. Actually, the internalization of transport external costs strongly favors the employment of the interports for sending/receiving by rail to/from other extra regional locations the containers disembarked/to be embarked at the Campanian seaports (Tab. 4). Hence, the rail transport's share on total two-way inland traffic between the regional interports and extra-regional locations is greater in the scenario internalizing the externalities compared with the other modelled scenario (Tab. 4). Anyhow, also in this latter scenario there is evidence of capacity saturation of the rail connections between the Campanian seaports and interports.

Table 3: Incidence of railway transport on inland container traffic from/to the Campanian seaports (real situation and modelled scenarios)

		From/to the port of Naples	**From/to the port of Salerno**	**From/to the ports of Naples and Salerno**
Railway's share on total inland traffic	*Observed real situation in 2007*	7.8%	0.0%	4.3%
	Modelled scenario without transport externalities	19.5%	2.3%	11.7%
	Modelled scenario with transport externalities	19.6%	2.5%	11.9%
Railway's share on inland traffic to/from the Campanian interports	*Observed real situation in 2007*	10.4%	0.0%	10.1%
	Modelled scenario without transport externalities	38.4%	79.7%	39.9%
	Modelled scenario with transport externalities	37.1%	82.0%	39.0%
Railway's share on inland traffic to/from other inland locations	*Observed real situation in 2007*	7.0%	0.0%	3.4%
	Modelled scenario without transport externalities	13.9%	1.5%	7.5%
	Modelled scenario with transport externalities	14.2%	1.5%	7.6%

Furthermore, the modelled scenarios present lower levels of internal logistic costs and external impacts of transport compared with the real situation (Tabb. 5-6). The negative impact of transport operations – in terms of air pollution, noise, greenhouse gases, accidents and congestion – have therefore been monetized also with regard to the real-life scenario as well as in the modelled scenario which does not incorporate the externalities in its objective function.

The internalization of transport external costs in the objective function stimulates rail-based container distribution solutions, while determining slightly higher internal generalized logistic costs and decisively lower external costs compared with the scenario without externalities. To sum up, the scenario with externalities features the lowest social total generalized inland logistic cost. It also features the lowest physical emissions of greenhouse gases and atmospheric pollutants deriving from port-hinterland transport.

As far as the optimal interport traffics in the modelled scenarios are more specifically concerned, a significant result of the analysis by Iannone (2010) and Iannone and Thore (2010) has been confirmed, both for import and export flows. Under an extended gateway system based on a regime of customs continuity between the regional seaports and interports, it would actually be possible to expand the port-hinterland.

Table 4: Incidence of railway transport on inland traffic from/to the Campanian interports for containers disembarked/embarked at the Campanian seaports (real situation and modelled scenarios)

	Observed real situation in 2007	**Modelled scenario without transport externalities**	**Modelled scenario with transport externalities**
Containers disembarked/embarked at Naples			
Railway traffic leaving/entering Nola and Marcianise (full and empty TEUs)	142	3,108	6,065
Railway transport's share on total inland traffic leaving/entering Nola and Marcianise	2.2%	9.5%	18.5%
Containers disembarked/embarked at Salerno			
Railway traffic leaving/entering Nola and Marcianise (full and empty TEUs)	0	114	1,117
Railway transport's share on total inland traffic leaving/entering Nola and Marcianise	0.0%	100.0%	100.0%
Containers disembarked/embarked at Naples and Salerno			
Railway traffic leaving/entering Nola and Marcianise (full and empty TEUs)	142	3,222	7,182
Railway transport's share on total inland traffic leaving/entering Nola and Marcianise	2.2%	9.8%	21.2%

Figure 3 reports the results of a sensitivity test calculating the variation of the optimal total transport external cost in function of the unit average port dwell time for import/export full containers cleared by customs under the modelled scenario with externalities. Compared with the base case, the dwell time changes taken into consideration are: (i) 50% reduction; (ii) 25% reduction; (iii) 25% increase; (iv) 50% increase. As the figure illustrates, the optimal cost is a declining function of the dwell time. The generalized port releasing cost's increases deriving from higher levels of dwell time favor the choice of clearing the loading units at the interports, determining a greater employment of rail services with associated external benefits from modal shift.

Figure 4 presents the impact of road transport fares' variations on the market share of rail transport on the optimal total inland flows of containers leaving and entering the Campanian seaports and interports under the modelled scenario without externalities. Compared with the base case, several road transport price scenarios are analyzed: (i) 90% reduction; (ii) 75% reduction; (iii) 50% reduction; (iv) 25% reduction; (v) 25% increase; (vi) 50% increase; (vii) 75% increase; (viii) 90% increase. It emerges that the maximum market share of rail transport which can be achieved is approximately constant under road transport prices' variations ranging between 50% and 90%.

Table 5: Internal, external and social total logistic costs for inland distribution of containers handled at the Campanian seaports (real situation and modelled scenarios)

	Observed real situation in 2007	**Modelled scenario without transport externalities**	**Modelled scenario with transport externalities**
Internal total generalized logistic cost for inland distribution of full and empty containers disembarked and embarked in Naples (millions of Euros)	*312.68*	*298.55*	*298.61*
Internal total generalized logistic cost for inland distribution of full and empty containers disembarked and embarked in Salerno (millions of Euros)	*128.42*	*128.13*	*128.26*
Internal total generalized logistic cost for inland distribution of full and empty containers disembarked and embarked in Naples and Salerno (millions of Euros)	***441.09***	***426.69***	***426.87***
External total cost for road and railway transport of full and empty containers disembarked and embarked in Naples and Salerno (millions of Euros)	*33.84*	*29.56*	*28.82*
Social total generalized logistic cost for inland distribution of full and empty containers disembarked and embarked in Naples and Salerno (millions of Euros)	***474.93***	***456.24***	***455.69***

In order to compare the effect of road fares' variations with the effect of the internalization of external costs, Table 7 presents the market share of rail transport at the Campanian seaports and interports under the different modelled scenario and the real life situation. It emerges that the effect of road fares' growth under the modelled scenario without externalities (see the fourth column of the table) is increasingly larger than that obtained by stimulating modal shift through the policy measure of internalizing the external costs (see the fifth column of the table).

Table 6: Atmospheric emissions from inland transport of containers handled at the Campanian seaports (real situation and modelled scenarios)

	Observed real situation in 2007	**Modelled scenario without externalities**	**Modelled scenario with externalities**
Total greenhouse gas emissions (CO_2+CH_4+N_2O) for road and rail transport of full and empty containers disembarked and to be embarked in Naples and Salerno (CO_2 eq. tonnes)	*111,319.4*	*100,492.0*	*98,660.3*
Total air pollutant emissions (CO+NO_x+PM+SO_2+VOC) for road and rail transport of full and empty containers disembarked and to be embarked in Naples and Salerno (tonnes)	*1,387.9*	*1,200.3*	*1,168.0*

Figure 3 – Total external cost of inland transport as a function of the average dwell time for full containers cleared by customs at the Campanian seaports (modelled scenario internalizing externalities)

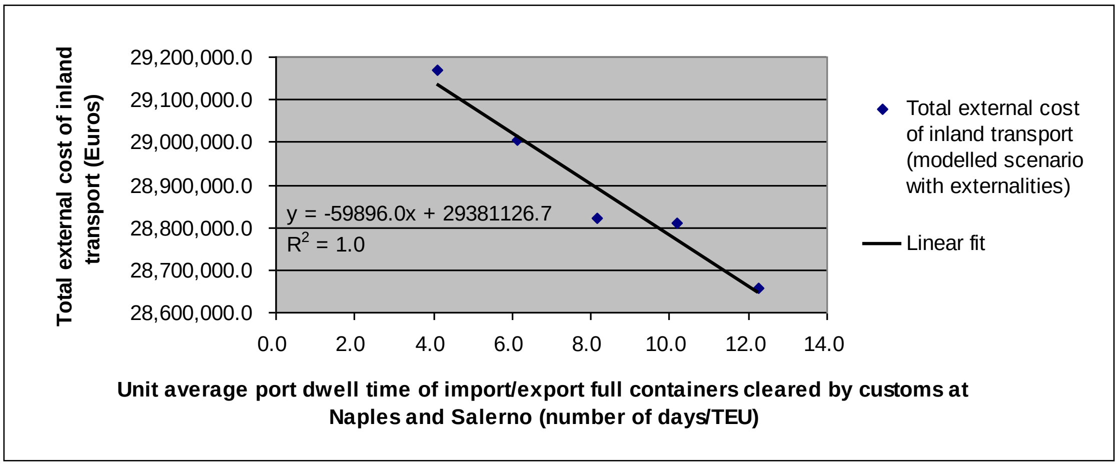


Figure 4 – Market share of rail transport on total inland flows from and to the Campanian seaports and interports as a function of road transport fares' variations (modelled scenario without externalities)

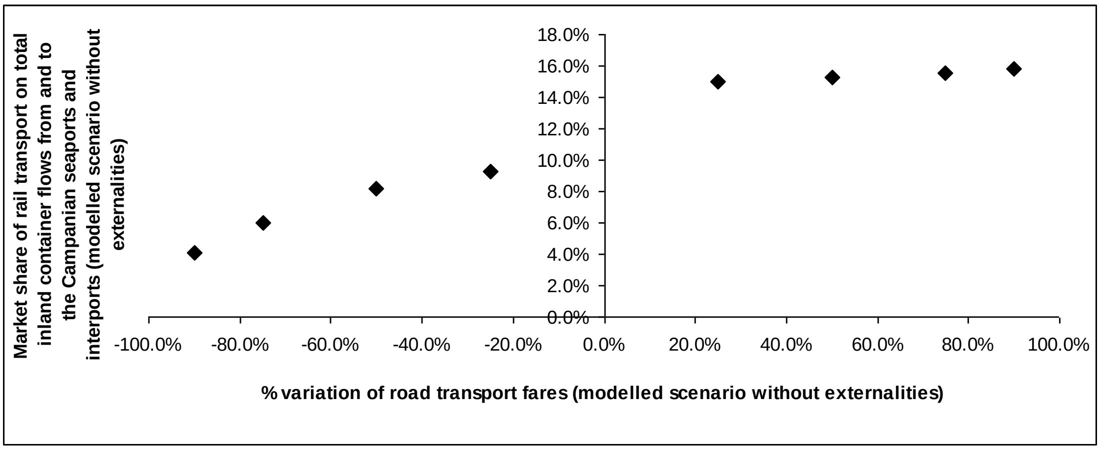


Table 7 – Comparison of road transport fares' variations and the internalization of transport external costs

Market share of rail transport on total inland container flows at the Campanian seaports and interports (observed real situation in 2007)	Market share of rail transport on total inland container flows at the Campanian seaports and interports (modelled scenario without externalities - BASE case)	% variation of road transport fares (modelled scenario without externalities - BASE case's variations)	Market share of rail transport on total inland container flows at the Campanian seaports and interports (as a result of the variation of road transport fares; modelled scenario without externalities - BASE case's variations)	Market share of rail transport on total inland container flows at the Campanian seaports and interports (modelled scenario internalizing externalities)
4.9%	14.3%	-90.0%	4.1%	14.9%
		-75.0%	6.0%	
		-50.0%	8.1%	
		-25.0%	9.2%	
		25.0%	15.0%	
		50.0%	15.3%	
		75.0%	15.5%	
		90.0%	15.8%	

4. CONCLUSIONS

For several years, the Campanian policy makers have been calling for more and more freight traffic to be shifted from road to rail. They have also been advocating a more active role of the interports in relieving the congestion phenomena induced by container traffic, especially in the port of Naples and over the road transportation system of the region. Nevertheless, the situation seems still far from showing any real sign of improvement. In such a context, more effective policy formulations need an in-depth assessment of the current and potential performances of the regional intermodal logistics system, and more specifically a detailed knowledge of its internal and external costs and of the driving factors behind them.

The case studies illustrated in this paper have highlighted the economic and social benefits arising from more advanced intermodal and customs procedures for the inland logistics of import/export containers transiting through the Campanian logistic system. In order to achieve greater efficiency and sustainability, it is essential to think holistically about the provision, regulation and use of the regional intermodal infrastructures and services.

The railway capacity of the short distance port-interport container connections in Campania can be further and even fully employed mainly through the introduction of more adequate regulations and more effective and intelligent organizational schemes and regional logistic marketing initiatives that should include:

- allowing also private rail traction companies to provide transit services under facilitated conditions between seaports and interports;
- supporting and promoting the interports of Nola and Marcianise in an equitable manner;
- sensitizing the awareness of direct and indirect supply chain benefits deriving from a real innovative regional extended gateway logistics system integrating seaports and interports.

As things stand today, the grant scheme proposed by the outgoing Campanian regional authority for transportation would not seem an appropriate policy solution. Such a scheme would provide the possibility of funding container shuttle trains between the port of Naples and the interport of Nola, while taking account of external benefits from modal shift (EU, 2009). As demonstrated in this paper, the internalization of the external diseconomies in the transport prices can only lead to a greater use of railway services between the regional interports and extra-regional locations.

Further extensions of the *interport model* could feature, for instance, safety stock cost parameters and be even applied to other container network systems in Europe, while also including barge transport and taking account of other specific logistics practices such as the port-hinterland distribution arranged by marine terminal operators.

REFERENCES

Amici della Terra, Ferrovie dello Stato (2005) The environmental and social costs of transport in Italy - Fifth Report, Rome.

Anciaux, D., Yuan, K. (2007) Green supply chain: intermodal transportation modeling with environmental impacts, Proceedings of the *European Transport Conference 2007*, Association of European Transport (AET) and contributors, Leeuwenhorst Conference Centre, The Netherlands.

Bauer, J., Tolga, B. and Crainic T.G. (2010) Minimizing greenhouse gas emissions in intermodal freight transport: An application to rail service design, *Journal of the Operational Research Society*, **61** (3) 530 -542.

Cetinkaya, B., Cuthbertson, R., Ewer, G., Klaas-Wissing, T., Piotrowicz, W. and Tyssen, C. (2011) *Sustainable Supply Chain Management. Practical Ideas for Moving Towards Best Practice*, Springer-Verlag, Berlin Heidelberg.

European Commission (2001) White Paper - European transport policy for 2010: time to decide, *COM(2001) 370 final*, Brussels.

European Commission (2007) Freight Transport and Logistics Action Plan, *COM(2007) 607 final*, Brussels.

European Commission (2008) Strategy for the internalisation of external costs, *COM(2008) 435 final*, Brussels.

European Commission (2011) White Paper - Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, *COM(2011) 144 final*, Brussels.

European Union (2009) Commission gives green light to Italian State aid for a new combined freight transport service, *IP/09/935*, Brussels.

Feng, C.-M., Huang, H.-H. (2005) The economic evaluation of intercity intermodal logistics, *Journal of the Eastern Asia Society for Transportation Studies*, **6** 2921-2936.

Global Commerce Initiative (2008) 2016 Future Supply Chain. Serving Consumers in a Sustainable Way, Capgemini.

Iannone, F. (2010) A model optimizing the port-hinterland logistics of containers: The case of the Campania region in Southern Italy, Proceedings of the *IAME 2010 Annual Conference*, International Association of Maritime Economists (IAME), Lisbon.

Iannone, F., Thore, S. (2010) An economic logistics model for the multimodal inland distribution of maritime containers, *International Journal of Transport Economics*, **37** (3) 281-326.

Janic, M. (2007) Modelling the full costs of an intermodal and road freight transport network, *Transportation Research Part D*, **12** (1) 33-44.

Lee, P.T.-W., Hu, K.-C. and Chen, T. (2010) External Costs of Domestic Container Transportation: Short-Sea Shipping versus Trucking in Taiwan, *Transport Reviews*, **30** (3) 315-335.

Liao, C.-H., Lu, C.-S. and Tseng, P.-H. (2011) Carbon dioxide emissions and inland container transport in Taiwan, *Journal of Transport Geography*, **19** (4) 722-728.

Macharis, C., Van Hoeck, E., Pekin, E. and Van Lier, T. (2010) A decision analysis framework for intermodal transport: Comparing fuel price increases and the internalisation of external costs, *Transportation Research Part A*, **44** (7) 550-561.

Mallidis, I., Dekker, R. and Vlachos, D. (2010) Greening Supply Chains: Impact on Cost and Design, *Econometric Institute Report EI 2010-39b*, Econometric Institute, Erasmus University Rotterdam.

McKinnon, A., Cullinane, S., Brown, M. and Whiteing, A. (eds.) (2010) *Green Logistics: Improving the Environmental Sustainability of Logistics*, Kogan Page, London.

Organisation for Economic Cooperation and Development-International Transport Forum (eds.) (2009) *Port competition and hinterland connections*, Paris.

Paksoy, T., Özceylan, E. and Weber, G.-W. (2010) A multi objective model for optimization of a green supply chain network, Proceedings of the *Third Global Conference on Power Control and Optimization*, Gold Coast, Australia.

Pan, S., Ballot, E. and Fontane, F. (2010) The reduction of greenhouse gas emissions from freight transport by pooling supply chains, *International Journal of Production Economics*, in press.

Sarkis, J. (2006) (ed.) *Greening the Supply Chain*, Springer, London.

United Nations Economic Commission for Europe (2010) *Hinterland Connections of Seaports*, New York and Geneva.

Wang, F., Lai, X. and Shi, N. (2011) A multi-objective optimization for green supply chain network design, *Decision Support Systems*, **51** (2) 262-269.

NOTES

[1] The *extended gateway* concept incorporates the idea that some seaport facilities and functions can be duplicated or complemented at hinterland locations. The term simply refers to a particular type of "trade facilitation" providing the possibility to rely on a regime of customs continuity between seaports and dry ports. Under extended gateway systems, customs authorities qualify dry ports as an integral part (that is an extension) of specific seaports. The containers can be transported between the seaports and dry ports without the need for customs transit documentation. Transport organization can be done by shipping lines and/or marine terminal companies, respectively in cases of carrier haulage and terminal operator haulage. This saves a great deal of time for the releasing operations in seaports and is the basis for sustainable transport. Merchants can delay the compliance of all customs formalities, while getting their containers released more closely to their customer base and possibly at a more certain point in time; marine terminal companies face less pressure on their facilities due to shorter port dwell times; inland intermodal connections can be better planned and utilized; governments can increase their revenue from taxes due to the positive link between trade facilitations and freight flows.

[2] In compliance with the customs regulations currently in force in Italy, only the railway transport permits the necessary conditions of fiscal safety related to the inland haulage without any accompanying inland transit document for containerized cargoes that have not been nationalized yet through customs clearance. Furthermore, due to an ancient customs legal regime still in force, at moment the incumbent Italian State-owned "Trenitalia" is the only company authorized to provide rail traction services under facilitated conditions for customs bonded containers traveling under the responsibility of shipping lines from/to the Italian seaports. In particular, Trenitalia is not obliged to arrange financial guarantees/surety policies covering the duties and taxes of containerized cargoes transported under customs bond.

[3] The network system of first-tier sea-land intermodal load centres in Campania encompasses the Mediterranean seaports of Naples and Salerno, and the interports of Nola and Marcianise. Both interports are located approximately 30 km from the port of Naples; furthermore, Nola is situated 57 km from the port of Salerno, while Marcianise 80 km. The distance between the two interports is just 32 km.
The main criticalities of the Campanian regional logistic system for intermodal traffic and particularly for inland distribution of maritime containers can be summarized as follows:

- port-hinterland still exclusively limited to the national scale;
- low rates of utilization of the existing rail transport capacity from seaports and interports;
- suspension of rail connections from/to the Salerno port;
- congestion over the road system throughout the region;
- port capacity saturation;
- severe congestion and high container dwell times at the Naples port also due to slow customs procedures;
- legal and technical barriers to a fair and non-discriminatory competition in rail traction services between seaports and interports.

At the moment, Trenitalia has ceased to offer railway services between the Campanian seaports and interports. The rail connection between Naples and Nola is currently employed only for merchant traffics and is operated by "Interporto Servizi Cargo", a private rail traction provider belonging to "Interporto Campano", the company in charge of the development and management of the Nola interport. Furthermore, just in 2010 the intermodal terminal and marketing company of the Marcianise interport ("Rail Services Logistics", ex "NAOS") has been authorized at operating a customs bonded "A3" area for international container operations, while only in 2011 an X-ray scanner has been installed within the interport.

[4] For the most part, empirical data have been collected through questionnaires and interviews to public bodies and private firms. Detailed information concerning can be obtained from the author upon request. Differently from earlier applications of the model (Iannone, 2010; Iannone and Thore, 2010), definitive figures on the average customs declared value of

containerized imports and exports in the Campania region during 2007 (equal to 18,589 Euros/full TEU and 24,920 Euros/full TEU, respectively) have been employed in this paper.