System Dynamics Simulation: an Application to Regional Logistics Policy Making

Alberto De Marco, and Carlo Rafele

***Abstract*—** The fast-pace development of trades with the Far East is giving the Mediterranean Sea the chance of becoming a major logistics hub. In the Mediterranean-front E.U. regions, public and private investments are aimed at this opportunity by integrating transportation networks, sea ports, and inland logistics platforms.

With specific regard to the North-West of Italy, a model based on System Dynamics has been simulated to help decision and policy makers in the task of planning and directing the investment effort. The model provides impact analysis of freight traffic flow trends in the region on the medium and long-term, as a result of the interaction between exogenous variables and different case-scenarios for road and railroad infrastructure investments.

***Keywords*—**Logistics, Italy, System dynamics, Policy making.

I. Introduction

Logistics increasingly impact on the competitive advantage of industrial systems because the cost of transportation and distribution does not affect product quality and value.

Globalization of trades, fast-growing Asian economies and delocalization of production sites require southern Europe to increase capacity and attractiveness for containerships crossing the Mediterranean Sea from the Far East to northern Europe and to the Americas through the Suez Canal.

Mediterranean ports are keen to become hubs to transiting flows, but major benefits to the region may be obtained from added-value logistic operations. In this sense, negative environmental factors due to increasing traffic flows may be compensated by local economic and social development.

To a smaller scale, the north-western Italy area (particularly, Piedmont and Liguria regions) perfectly suits the problem.

The region is a major crossroads of commerce and mobility at the intersection of the European Corridors V Lisbon-Kiev, and XXIV Genoa-Rotterdam, with a strong manufacturing environment and a good level of infrastructures: roads, railroads and logistic platforms.

However, the growing traffic flows face infrastructures congestion and inefficient logistic services.

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To a better insight, the expansion of the deep port of Genoa (as well as other Liguria's harbors) is limited by the mountains that wildly separate the Tyrrhenian Sea from the large and wealthy plain to the north, where most of the largest and productive cities in Italy are located.

Yet, port operations need more and more space due to the growing usage of containers. Capacity, handling efficiency and value-added logistic services are the key factors to attract containership traffics to a port than to another.

Liguria and Genoa have very deep water to host mega-containerships, but spaces for logistic services are unavailable: inland harbors have to be created north of the mountains as an integrated logistics platform system.

Local governments and private entities have just started the investment process aimed at being part of the game of global traffic flows [1]. But this is still underway and partly behind schedule compared to some competitor regions in Spain and northern Europe.

Disadvantages for the process to be successful are inherent with the geographical positioning constrained by the Alps, and with the economic environment based on small and medium logistic players. Indeed, the most important weakness is that no strategic planning has been done to lead the task.

rth-western Italy still requires plans and directions to invest in effective inland logistic platforms.

The candidate hosts of an appropriate dry harbor for Genoa are the nodes close to the city of Alessandria (between Genoa and Milan) and the city of Novara (between Torino and Milan).

The first one is closer to Genoa, but the second is also at the intersection with the east-west corridor V and has intense commerce relationships with northern-European ports, such as Rotterdam and Hamburg. The longer distance to Genoa is actually irrelevant, since handling and customs lead-times have high incidence on the total transportation time to the site.

In both areas chaotic and unplanned logistic investments have been performed or are underway in the field of transportation infrastructures and logistics businesses. The actual capacity of five million square meters of logistic platforms is supposed to be tripled in a few years.

II. Modeling for Policy Design

To support the capacity expansion planning process in a coordinated and effective manner, a simulation model has been developed out of a research study aimed at understanding the complex system of logistics in the region

[2].

In particular, the problem of locating the dry harbor is influenced by non-linear and recurring interactions with a number of variables related to g/local traffic flows. The model is designed to capture the status of the logistic system and to forecast future dynamics.

The model is based on the System Dynamics approach [2]. System Dynamics is a computer-based simulation method that allows the modeler to graphically represent a system of differential non-linear equations and to have the computer do the discrete-step computational effort over a preset time frame [3].

The outcome of the simulation is the set of curves that describe the behavior of all variables on the time axis. Validation of the model is based on historical data and sensitivity analysis. This allows understanding the overall dynamics of the system, the influence of independent and dependent variables to the problem, and, finally, to support decision making and testing policy design by making simulations of different case-scenarios [4].

Before entering the regional logistics model in details, a few notions of System Dynamics are presented. References are provided for more information.

A. Glimpse of System Thinking

The System Dynamics theory is jointly related to system thinking: causes and effects are not linear in time and space, but multiple feedback loops interact as variables of a complex system.

Typically, a Causal Loop Diagram is a graphical qualitative representation of the relationships between interrelated factors affecting a system and, obviously, its problems.

Figure 1 is a Causal Loop Diagram example of a simplified problem of freight traffic growth in a logistics platform: the reinforcing loop (letter "R" in the graph) illustrates the exponential increase of traffic because, the more the handling efficiency – and its cost for customers –, the more the volumes, which, in turn, allow for even more efficiency as an effect of scale, and consequently more traffic, leading to a

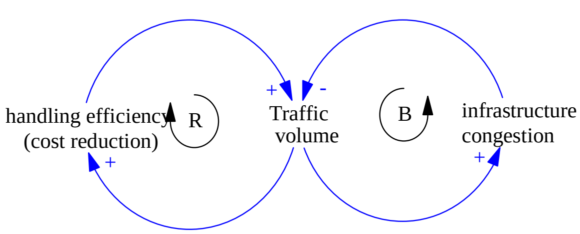

Fig. 1 Example of causal loop diagram

virtually infinite positive escalation.

Yet, one or more balancing loops usually limit exponential growth. Thus, the infrastructure congestion loop (letter "B" in Figure 1) reduces the traffic volume expansion up to an equilibrium point, which is the maximum capacity of existing infrastructures [5]. A balancing loop usually creates an oscillation in the dynamics of the system, especially if a delay

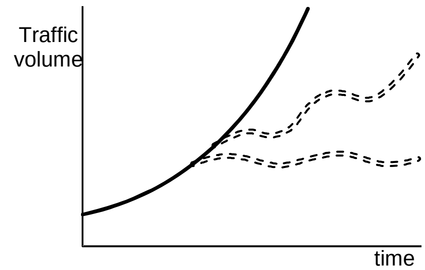

Fig. 2 Goal seeking for the 'traffic volume' variable

occurs between the cause and the effect (Exhibit 2).

B. System Dynamics Modeling and Computer Simulation

The causal loop representation requires defining all variables and mutual relationships in a system.

Then, to obtain a quantitative outcome and analyze the system behavior, it is necessary to translate the influence diagram into a computer-compliant "System Dynamics model" enabling calculations of a number of simultaneous feedbacks (several software packages are available, such as iThink, High Performance Systems, Hanover HA, U.S.A.; Vensim, Ventana Systems, Harvard MA, U.S.A.; Powersim, Model1Data, Bergen, Norway).

The computer-simulation model involves physical variables considered as stocks and flows, as well as writing the equations for all the relationships between variables to have a system of both linear and non-linear differential equations.

Figure 3 is an example of "stock&flow" diagram, which describes the process of supplies coming in an inventory. The equations for the example are provided below (please note

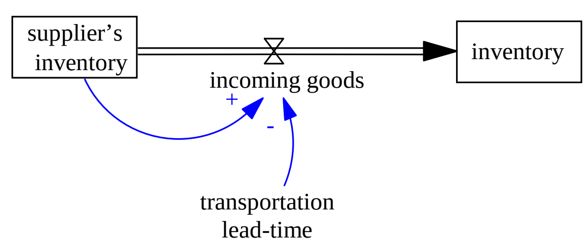

Fig. 3 Example of stock&flow diagram

that the syntax may change depending on the software package).

Stock: inventory = INTEG(incoming goods)dt ; INITIAL: 0 (1)

Flow or rate: incoming goods = supplier's inventory / transportation lead-time (2)

This example shows that System Dynamics allow for analyzing complex situations by using fairly simple software tools that can be learnt and applied to practical problems [6].

C. Reference Models

In the context of transportation and logistics, System Dynamics integrate economics, society and environment, while traditional analyses would rather use separate indices with regard to each area without considering their interactions.

According to Yevdokimov's transportation sustainability model [7], System Dynamics simulation studies both vertical and horizontal relations. Status and flow variables are horizontally linked (e.g. energy consumption for transportation is the relationship between the stock of resources and their current usage).

Vertical links relate to the ability of System Dynamics to understand sustainability criteria based on integrated development factors.

According to the model, the feedback loops are composed of both individual links between endogenous variables (stocks and flows) and aggregated vertical sustainability relationships.

A second relevant model to the one proposed in this paper is the land use/transportation system [5]. This is a mixed System Dynamics and Agent-Based model to understand the relationship between transportation demand and land use.

This paper also draws on future transportation architecture hypothesis [8]. This was investigated because it attempts to improve existing infrastructure performance as well as because describes the relationships between the desired infrastructures and their availability.

III. Case-study Modeling

Basically, the strategic problem of locating a new logistics platform to serve as a dry harbor for Genoa is about investigating the main traffic flows with regard to the quantities of freight related to the port of Genoa; the quantities of goods from and to Genoa that cross the inland region, but bypass local logistic operations (transiting traffic flows); and the volumes of goods from and to the port that take advantage of inland logistics operations (stocked traffic flows).

The model design and simulation aims are the following:

1) Assessing the necessity and worth of creating a new logistics inland port. This is measured in terms of optimal capacity compared to the actual available one.
2) Determining the degree of concentration, or fragmentation, of logistics spaces and how to adjust investments between the two mentioned geographical areas, namely Alessandria and Novara. This can be done also by investigating the type - collaborative or competitive – of dynamic relationships between the two sites.

A. Qualitative Modeling: the Causal Loop Diagramming

The influence diagram (model and simulation are partly presented in this paper due to space constraints; please ask authors for complete graphical representation and system dynamics model) drawn to qualitatively capture the system feedbacks between traffic variables can be mainly subsumed into five areas, namely: 1) the sea traffic feedbacks between real sea traffic and port capacity; 2) the inland transiting traffic feedbacks that involve infrastructure connections with the sea port of Genoa; 3) the inland transiting traffic flows that do not involve the port, i.e.: east-west and north directed flows; 4) the traffic flow stocked in Novara for added-value logistic operations; 5) the traffic flow stocked in Alessandria for added-value logistic operations.

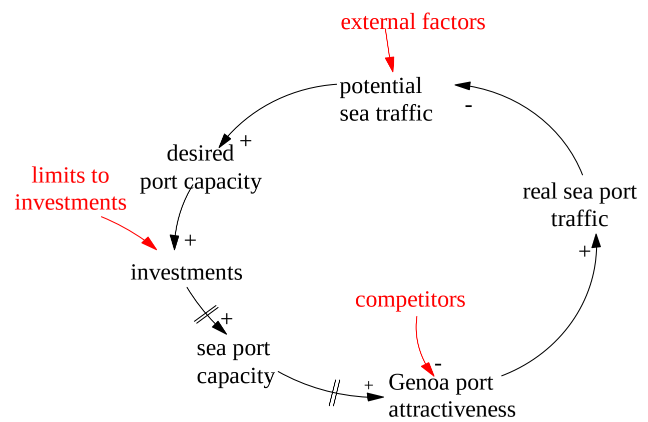

Fig. 4 Feedback loop describing the dynamics of satisfaction of potential traffic demand

Several loops exist within and between all areas. For example, the sea traffic area includes the balancing loop that assures the 'satisfaction of potential traffic demand' (Figure 4).

The variable 'Potential sea traffic' represents the demand to be fulfilled, which is driven by exogenous factors related to Far-East traffic trends. The more the 'Potential sea traffic', the more is the 'Desired port capacity'. This, in turn, triggers investments in port infrastructure projects that, with a delay for construction, lead to the increase of real 'Sea port capacity' and attractiveness for traffic flows. As a consequence, the growth of real traffic volumes fulfills the demand and the 'Desired capacity', thus reducing investments and attractiveness in the next period. The recurrence of the loop creates an oscillating goal-seeking behavior.

Similarly, in the transit areas of the model the main feedbacks loops are the balancing one that illustrates the process of fulfilling the desired capacity of inland logistics platforms, and the reinforcing one representing the relationships between capacity and infrastructure congestion. The latter feedback is somewhat counterintuitive: the more the capacity, the more the attractiveness and so the traffic leading to congestion.

The model also includes loops across different areas, such as the dynamic relationship prey-predator between the Novara and Alessandria regions, as well as the oscillating influence between congestion and attractiveness.

B. Quantitative Modeling: Stock&Flow Diagramming

The stock&flow model declines three main systems of factors, namely: freight flows, investments in infrastructures, attractiveness and traffic shares.

Basically, those factors are part of a general feed back: site attractiveness, which depends on both actual traffic flows and potential demand and infrastructure availabilities, is the source of traffic flows coming in and out a site and, in turn, of site appeal itself.

Traffic flows are divided into sea traffic and inland traffic flows, decomposed into transiting and stocked quantities for account with regard to projects that are planned or yet underway in the region from 2007 to 2016.

Those include local road and railroad network optimizations, as well as large projects planned to bore new tunnels through the mountains (Lötschberg, third pass from Genoa, etc.).

On the contrary, investments in logistic platforms are the output variables in the model aimed at providing support for

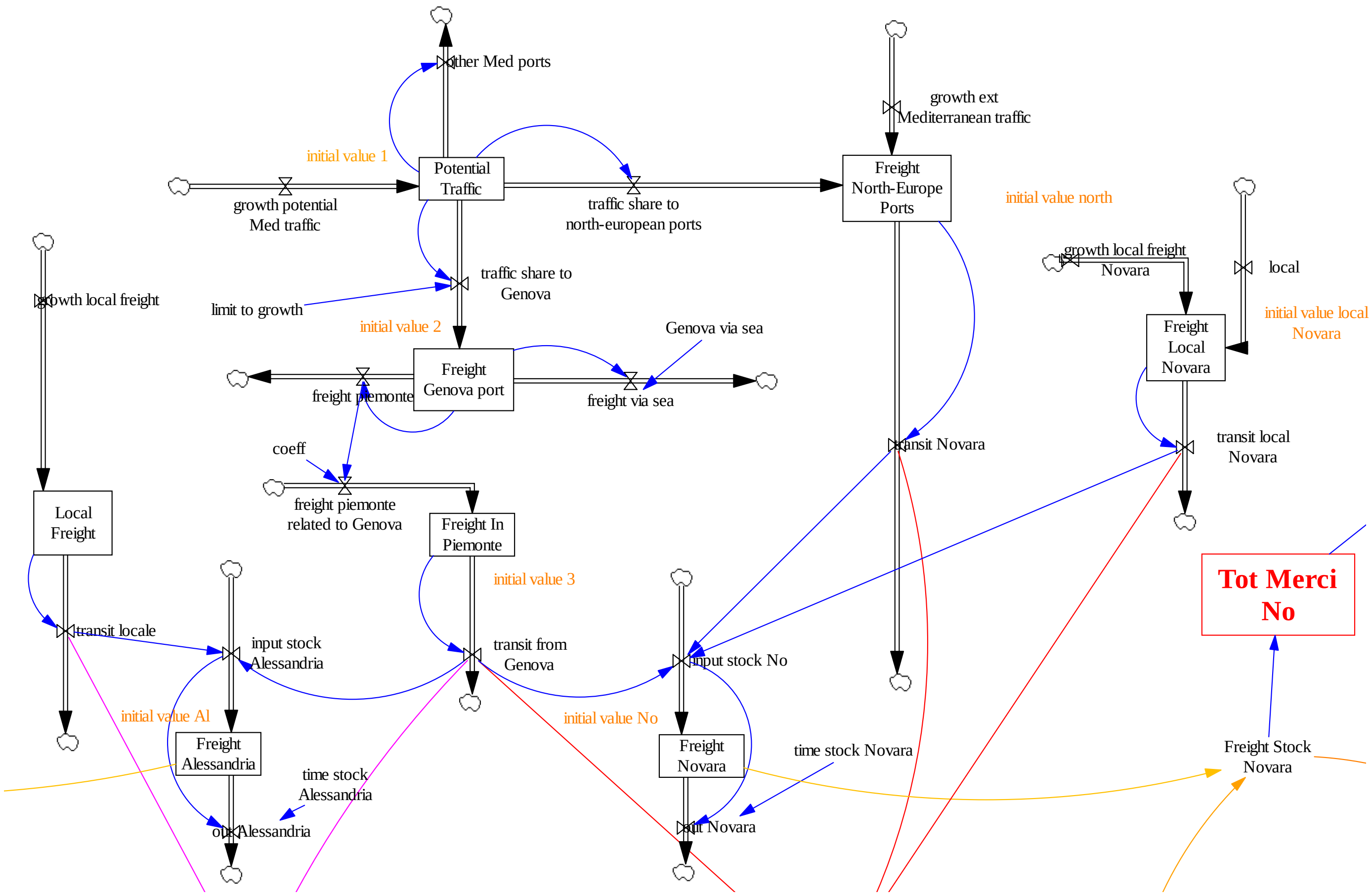

Fig. 5 Overview of the stock&flow logistics model: the system of freight flows

both sites (Figure 5 is provided as a sample. The complete model and set of differential equations are in the Appendix). The potential traffic share that goes to Genoa is not an exogenous variable, since it is conditioned by port infrastructures, by Novara's inland port attractiveness, as well as by the appeal of north-European ports. Real traffic flows are determined by comparing demand and infrastructure offering; only part of those flows is stocked for logistics operations. After goods have been processed they get out of the inland platform and become transiting flows. In the model, because of a primary distribution vocation, Novara's lead-times are shorter than in Alessandria where longer added-value manufacturing operations are traditionally made. Here, the smaller turnover is calibrated by a greater economic unit value.

As far as investments are concerned, a large quantity of exogenous variables (independent) have been taken into decision making, namely the size and point in time for required investments. The focus is on the total investment and on its repartition between the two sites as well as on their effects over time.

There is no space here to provide explanations of other feedback areas in the entire model, but details and complete model equations can be requested to the authors.

IV. Case-Study Simulation

A. Inputs and Outputs

The inputs to the model are the size and the timing of investments in both geographical areas (i.e. Novara and Alessandria). The first are referred to as the capacity dimensioned as TEU per month TEU is the twenty feet equivalent container unit. The timing, expressed in months, is referred to as the date when the additional capacity will be available as the result of planned and in progress logistic platform projects.

The most important output is the cumulative curve of stocked freight over the simulation timeframe. Also, since larger quantities do not necessarily involve greater return on investments, to better analyze the profitability of different case-scenarios Net Present Value (NPV) evaluations have been introduced using third party sources that allow determining value generated from processed stocked goods [10].

Thus, the comparison of incremental values of both freight and NPV cumulative curves gives more significant results than their total values.

B. Timeframe and Model Validation

The simulation provided runs for a 21-year timeframe, from January 2000 to December 2020.

The unit time step is a month.

The first five years of simulation results are compared to

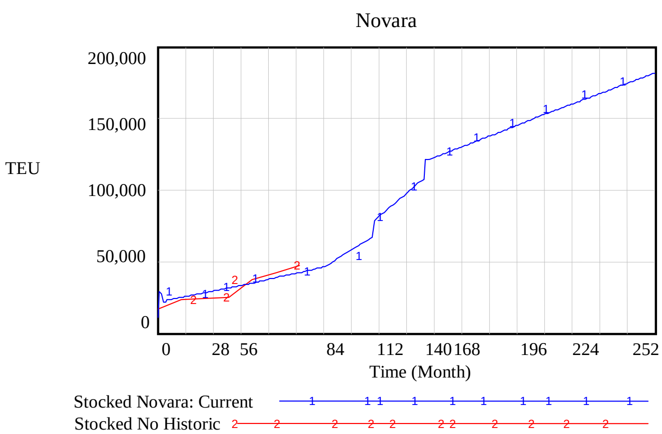

Fig. 6 Model validation for variable: stocked freight in Novara

available historic data series in order to retrospectively validate the entire model (sample is in Figure 6). From January 2005 results are supposed to anticipate future trends.

Also, a sensitivity analysis has been performed for input variables and this has demonstrated the model substantial robustness.

C. Simulation results and policy design

The Vensim software simulations have been performed by reiteration. The investigated problems (namely: opportunity of the dry harbor, its degree of optimal distribution, and the timing to make investments) are non independent, but, for computational reasons, have been first calculated by assuming independency. Then, after local optimizations have been obtained, such values have been applied to sub-problems up to a general stability status.

The presented values are the ones associated with the global optimal solution. They are the results of two main hypotheses: as time passes by, investments for enhancing the Genoa port capacity are progressively continuous as well as trade relationships between the port and the inland platforms.

Following are the policy-making directions provided by the simulation with regard to the analyzed problem and sub-problems.

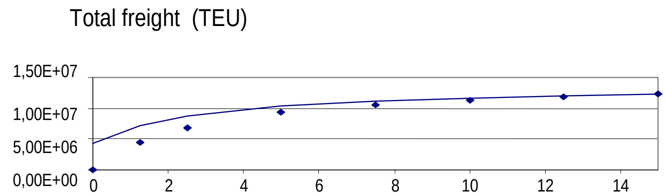

Fig. 7 Curve of total freight as a function of increasing investments

Main problem: opportunity of expanding the capacity of an inland harbor. Here output cumulative curves for total freight and NPV of total investments increase monotone (Figures 7).

Under the assumption of unlimited financial resources, the optimal investment would be the one associated with the maximum surface available. Yet, it is clear that effectiveness and profitability decreases as total investment grows.

Sub-problem 1: optimal degree of concentration or fragmentation of inland harbors. Figure 8 shows how the maximum quantity of stocked freight is obtained when the total investment, worth 10 million sq. meters, is equally shared between both sites. Directing investments to only one site would result in penalizing the total stocked traffic benefits. By applying the bisection method, the optimal investment repartition is 41% to Alessandria and 59% to Novara. Similar results are provided by analyzing the NPVs.

TOTAL FREIGHT [teu]

Alessandria	DISTRIBUTION OF TOTAL INVESTMENT				
100%	5,12E+06				
75%		1,04E+07			
50%			1,127E+07		
25%				1,12E+07	
0%	0,00E+00				7,11E+06
	0%	25%	50%	75%	100%
	Novara				

Fig. 8 Quantity of stocked freight as a function of investment sharing between Novara and Alessandria

In case circumstances require concentrating capacity, further analyses suggest that more investments in Novara cause less harm than enhancing capacity solely in Alessandria.

Sub-problem 2: timing for investing in inland harbors. Inland logistic platforms are made available after construction projects have been completed. In the best-case scenario considered in the simulation, the first additional capacity will be on hand no earlier than January 2009, while projects will accomplish no later than 2014. The more investments are delayed, the more potential traffic share is absorbed by competitors and, thus, the more cost-opportunity.

Figure 9 shows the NPV as a function of the time [months] when additional capacity is available in both sites. From the

NPV (€)			
Alessandria	Novara		
	108	144	180
108	**1,54E+09**	1,38E+09	1,14E+09
144	1,50E+09	1,35E+09	1,10E+09
180	1,37E+09	1,22E+09	9,92E+08

Fig. 9 NPV of investments in additional capacity as a function of time

simulation data, the obvious concept of anticipating investments is confirmed, but still Novara takes the lead in effectiveness.

V. Conclusion

This work presents a model to provide fundamental policy directions for planning logistics investments, with regard to the need of creating a dry harbor in north-western Italy to support Genoa's shipping operations. In particular, this considers the dilemma of locating a new major logistic platform with choice between two sites, namely: Novara and Alessandria.

The simulation analysis indicates that the best results for the overall system are obtained when investments are equally shared between both sites and anticipated as soon as possible, with priority to the Novara's platform.

In general terms, this work is aimed at providing a decision making tool based on scientific evidence; to this end, the System Dynamics method is used to provide a simple and informative method for policy makers.

The model basically provides approximate future behaviors of the variables affecting the system because quantitative results are based on historical data validation.

Appendix

Following is the set of differential equation of the model.

(001) Alessandria area stock offering=initial stock Al+investments stock Al+previous investments Alessandria ; Units: TEU

(002) area offering stock No= initial stock Novara+investments stock No+previous investments Novara ; Units: TEU

(003) attractiveness=(weight Alessandria*attractiveness Al+weight Novara*attractiveness Novara)/(weight Alessandria+weight Novara) ; Units: Dmnl

(004) attractiveness Al=(delay stock Al*weight stock Al+delay transit Al*peso transit Al)/(weight stock Al+peso transit Al) ; Units: Dmnl

(005) attractiveness Novara=(dealy stock No*weight stock No+delay transit Novara*weight transit No)/(weight stock No+weight transit No)

Units: Dmnl

(006) attractiveness Novara north=(dealy stock No*peso stock No nord+delay transit Novara*peso transit No nord)/(peso stock No nord+peso transit No nord) ; Units: Dmnl

(007) attractiveness stock No=(1+(area offering stock No-Freight Novara)/MAX(Freight Novara,area offering stock No))/2+Freight Stock Novara/stock max ; Units: Dmnl [0,1]

(008) attractiveness transit Al=(1+(network offering Al-network usage Al)/MAX(network usage Al,network offering Al))/2 ; Units:Dmnl [0,1]

(009) attrattivita stock Al=(1+(Alessandria area stock offering-Freight Alessandria)/MAX(Freight Alessandria,Alessandria area stock offering))/2+Freight Stock Alessandria/stock max ; Units: Dmnl [0,1]

(010) attrattivita transit No=(1+(offering infrastucture network Novara-network usage Novara)/MAX(network usage Novara,offering infrastucture network Novara))/2; Units: Dmnl [0,1]

(011) base Ge=0.1 ; (012) base north=0.1 ; (013) base Novara from north=0.165 ; (014) base stop Ge=0.3 ; (015) base stop local Al ; (016) base stop local Novara ; Units: Dmnl [0,1]

(017) base stop No from north=0.04

(018) coeff=1 Units: Dmnl [0,2]

(019) current network demand Al=transit from Genova+transit locale+other traffic Alessandria Units: TEU/Month

(020) current Novara network demand=transit from Genova+transit Novara+Other Traffic Novara+transit local Novara Units: TEU/Month

(021) dealy stock No=DELAY FIXED(attractiveness stock No,time delay,0.5) Units: Dmnl

022) delay stock Al= DELAY FIXED(attrattivita stock Al,time delay,0.5) Units: Dmnl

(023) delay transit Al=DELAY FIXED(attractiveness transit Al,time delay,0.5) Units: Dmnl

(024) delay transit Novara=DELAY FIXED(attrattivita transit No,time delay,0.5) Units: Dmnl

(025) expected share Units: Dmnl [0,1]

(026) FINAL TIME = 252 Units: Month The final time for the simulation.

(027) Freight Alessandria= INTEG (+input stock Alessandria-out Alessandria,initial value Al) Units: TEU

(028) Freight Genova port= INTEG (+traffic share to Genova-freight piemonte-freight via sea,initial value 2) Units: TEU [0,?]

(029) Freight In Piemonte= INTEG (freight piemonte related to Genova-transit from Genova,initial value 3) Units: TEU [0,?]

(030) Freight Local Novara= INTEG (growth local freight Novara+local-transit local Novara,initial value local Novara) Units: TEU

(031) "Freight North-Europe Ports"= INTEG (growth ext Mediterranean traffic+"traffic share to north-european ports"-transit Novara,initial value north) Units: TEU

(032) Freight Novara= INTEG (+input stock No-out Novara,initial value No) Units: TEU

(033) freight piemonte=Freight Genova port/TIME STEP*Piemonte Units: TEU/Month

(034) freight piemonte related to Genova=freight

piemonte*coeff Units: TEU/Month

(035) Freight Stock Alessandria=MIN(Freight Alessandria,Alessandria area stock offering) Units: TEU

(036) Freight Stock Novara=MIN(Freight Novara,area offering stock No) Units: TEU

(037) freight via sea=Freight Genova port*Genova via sea/TIME STEP Units: TEU/Month

(038) Ge stop=base stop Ge*(delay stock Al*weight Al stock+dealy stock No*weight No stock)/(weight No stock+weight Al stock) Units: Dmnl [0,1]

(039) Ge stop Al=1-Ge stop No Units: Dmnl

(040) Ge stop No=MAX(MIN(IF THEN ELSE((attractiveness Al+attractiveness Novara)>0, Ge stop*attractiveness Novara/(attractiveness Al+attractiveness Novara),0),1), 0) Units: Dmnl [0,1]

(041) Genova via sea=0.1 Units: Dmnl [0,1]

(042) growth ext Mediterranean traffic Units: TEU/Month

(043) growth local freight Units: TEU/Month

(044) growth local freight Novara Units: TEU/Month

(045) growth potential Med traffic Units: TEU/Month

(046) initial network Al=1e+007 Units: TEU/Month [0,?]

(047) initial rete No=1.2e+007 Units: TEU/Month [0,?]

(048) initial stock Al=900000 Units: TEU [0,?]

(049) initial stock Novara=600000 Units: TEU [0,?]

(050) INITIAL TIME = 0

(051) initial value 1=2.055e+006 Units: TEU [0,?]

(052) initial value 2=560000 Units: TEU [0,?]

(053) initial value 3=100000 Units: TEU [0,?]

(054) initial value 4=200000 Units: TEU [0,?]

(055) initial value Al=220000 Units: TEU [0,?]

(056) initial value local Novara=220000 Units: TEU

(057) initial value No=220000 Units: TEU [0,?]

(058) initial value north=2.546e+006 Units: TEU [0,?]

(059) input stock Alessandria=transit from Genova*Ge stop Al+transit locale*Local stop Al Units: TEU/Month

(060) input stock No=transit from Genova*Ge stop No+transit Novara*stop No from north+Local stop No*transit local Novara Units: TEU/Month

(061) investments in infra network Novara Units: TEU/(Month*Month)

(062) investments stock Al=STEP(investments stock Alessandria,timing investments stock Al) Units: TEU

(063) investments stock Alessandria=5e+006 Units: TEU [0,1.7e+007]

(064) investments stock No=STEP(investments stock Novara,timing investments stock Novara) Units: TEU

(065) investments stock Novara=5e+006 Units: TEU [0,1.7e+007]

(066) limit to growth Units: TEU/Month

(067) local Units: TEU/Month

(068) Local Freight= INTEG (+growth local freight*(1+attractiveness)-transit locale,initial value 4) Units: TEU

(069) Local stop Al=MAX(MIN(base stop local Al*(1+delay stock Al), 1), 0) Units: Dmnl [0,1]

(070) Local stop No=MAX(MIN(base stop local Novara*(1+dealy stock No), 1), 0) Units: Dmnl [0,1]

(071) network investments Al Units: TEU/Month/Month

(072) network offering Al= INTEG (network investments Al,initial network Al) Units: TEU/Month

(073) network usage Al=MIN(current network demand Al,network offering Al) Units: TEU/Month

(074) network usage Novara=MIN(current Novara network demand, offering infrastucture network Novara) Units: TEU/Month

(075) offering infrastucture network Novara= INTEG (investments in infra network Novara, initial rete No) Units: TEU/Month

(076) other Med ports=Potential Traffic/TIME STEP*other mediterranean ports Units: TEU/Month

(077) other mediterranean ports=1-share Genova-share north Units: Dmnl [0,1]

(078) other traffic Alessandria Units: TEU/Month [0,?]

(079) Other Traffic Novara Units: TEU/Month [0,?]

(080) out Alessandria=DELAY FIXED(input stock Alessandria,time stock Alessandria,0) Units: TEU/Month

(081) out Novara=DELAY FIXED(input stock No,time stock Novara,0) Units: TEU/Month

(082) peso stock No nord=1-peso transit No nord Units: Dmnl [0,1]

(083) peso transit Al=0.5 Units: Dmnl [0,?]

(084) peso transit No nord=0.7 Units: Dmnl [0,1]

(085) Piemonte=MAX(MIN(expected share*(1+attractiveness),1), 0) Units: Dmnl

(086) Potential Traffic= INTEG (+growth potential Med traffic-other Med ports-traffic share to Genova-"traffic share to north-european ports",initial value 1) Units: TEU [0,?]

(087) previous investments Alessandria Units: TEU

(088) previous investments Novara Units: TEU

(089) SAVEPER = TIME STEP Units: Month [0,?] The frequency with which output is stored.

(090) share Genova=MAX(MIN(base Ge*(1+attractiveness),1), 0) Units: Dmnl [0,1]

(091) share north=MAX(MIN(base north*(1+attractiveness Novara north),1-share Genova), 0) Units: Dmnl [0,1]

(092) share Novara from north=MAX(MIN(base Novara from north*(1+attractiveness Novara north),1), 0) Units: Dmnl [0,1]

(093) stock max=1.7e+007 Units: TEU

(094) stop No from north=MAX(MIN(base stop No from north*(1+dealy stock No), 1),0) Units: Dmnl [0,1]

(095) time delay=1 Units: Month [0,?]

(096) TIME STEP = 1 Units: Month [0,?] The time step for the simulation.

(097) time stock Alessandria=0.5 Units: Month [0,?]

(098) time stock Novara=0.25 Units: Month [0,?]

(099) timing investments stock Al=120 Units: Month [0,?]

(100) timing investments stock Novara=108 Units: Month [0,?]

(101) Tot Freight Al= INTEG (Freight Stock Alessandria/udm,0) Units: TEU

(102) Tot Merci No= INTEG (Freight Stock Novara/udm,0) Units: TEU

(103) Total Freight=Tot Freight Al+Tot Merci No Units: TEU

(104) Total Investments=investments stock Alessandria+investments stock Novara Units: TEU

(105) traffic share to Genova=MIN(Potential Traffic*share Genova/TIME STEP,limit to growth) Units: TEU/Month

(106) "traffic share to north-european ports"=Potential Traffic*share north/TIME STEP Units: TEU/Month

(107) transit from Genova=Freight In Piemonte/TIME STEP Units: TEU/Month

(108) transit local Novara=Freight Local Novara/TIME STEP Units: TEU/Month

(109) transit locale=Local Freight/TIME STEP Units: TEU/Month

(110) transit Novara="Freight North-Europe Ports"/TIME STEP/2*share Novara from north Units: TEU/Month

(111) udm=1 Units: Month [1,1]

(112) weight Al stock=3 Units: Dmnl [0,?]

(113) weight Alessandria=3 Units: Dmnl

(114) weight No stock=1 Units: Dmnl [0,?]

(115) weight Novara=2Units: Dmnl

(116) weight stock Al=1-peso transit Al Units: Dmnl [0,?]

(117) weight stock No=-weight transit No Units:Dmnl [0,1]

(118) weight transit No=.55 Units: Dmnl [0,1].

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