Simulation Based Design for a Railway Logistics Re-Engineering Project

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Abstract - In the last decades globalization dynamics have determined a continuous increase in freight flows and a growing global competition for the interception of these flows. This had a tremendous impact on the global supply chains configuration especially on ports, which must be able to handle an increasingly quantity of goods and to quickly ship them towards the consumer and production markets.
In order to be able to do that, ports needs more and more space and, at the same time, they require an efficient organizational model for effectively manage so a big quantity of cargo. However many ports, being embedded in the city fabric, can't easily enlarge their borders for gaining new space and therefore they are obliged to look for new areas in the hinterland. These inner areas represents an extension of the ports borders and they are managed just as they were part of the maritime domain: for this reason they are called "dry ports".
For an effective working of the "port-dry port" system, it is fundamental, among other things, that the related transportation infrastructures are suitable and functional to sustain the current and forecast freight flows.
This paper regards the analysis of the railway system that joints Genoa port principal container terminals with an hypothetical dry port set in Alessandria, 90 km far from Genoa, with the objective of studying the possible infrastructural criticalities and suggesting proper solutions.
To this aim, a simulation model has been developed and tested. The paper proposes the Discrete Event Simulation utilizing Arena software supported by MySQL Data Base Management System. Experimental design techniques (DOE) and neural networks have been utilized as an effective tool to produce an adequate experimental campaign and to study the response surface obtained.

***Keywords* —** Discrete event simulation, dry ports, freight transportation, logistics, railway terminals.

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I. INTRODUCTION

The proposed system takes into account:

- three container terminals in Genoa port: SECH-Southern European Container Hub, Messina and VTE-Voltri Terminal Europa;
- two connection railway lines (Genoa-Ovada-Alessandria and Genoa-Arquata-Alexandria) that allow a shuttle service;
- an hypothetical dry port settled in Alessandria, which is at Genoa port disposal providing logistical and transportation services, including customs controls.

Two different scenarios (A and B) will be analyzed: the first considers the existing infrastructure of "Alessandria Sorting"; the second assumes the construction of a brand new dry port.
It has been assumed that trains leaving from Genoa and arriving in Alessandria will go through the Genoa-Ovada-Alessandria section, while trains in the opposite direction will utilize the Genoa-Arquata-Alessandria line, as shown in Fig.1. This choice has been made to allow the shuttle service, that implies fixed schedule trains with a fixed car composition.

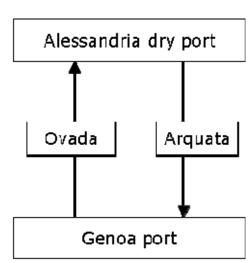


Fig.1 Flow model

The three container terminals are characterized by different throughput and modal split (in 2004 Sech and VTE moved approximately 15% of their traffic on railway, Messina around 80%).
In particular Sech terminal has a railway terminal in the root quay, consisting of 3 routes of about 500 m long in which convoys of 20 cars can be formed. It has an average capacity of forming 6 trains with 50 TEU per day in import or export. The train average waiting time for testing the train braking system is 40 minutes.
Messina terminal has 5 railway lines at its disposal (4 of which are 450 m long and the 5th is 500 m), of which only 3 are utilized. Trains are loaded through reach stakers and not with yard cranes. With the current railway structure 11 trains with 18 cars each are realized (import/export).
Finally VTE, which represents the biggest gateway container terminal in Italy, has a current capacity of forming trains of 800 TEU per day (2200 TEU/day in the foreseen capacity).
The railway operative model is the following: through a railway shunting with diesel locomotives, trains must be brought from terminals to a railway park in which they are connected to the electric line for their shipping in the hinterland, beyond the Apennines.
Campasso and Sampierdarena Sorting railway parks can be utilized both for Messina and Sech terminals. In particular, for the locomotive changing there are 7 railway routes available in Sampierdarena Sorting, which is utilized for trains leaving Genoa Port, and 4 in Campasso, used for trains arriving from Alessandria to Genoa.
VTE terminal is instead supported by Voltri station, which is located very close to Voltri terminal and it has 4 available routes for the locomotive changing and 1 for the connection with the terminal. The line connecting Voltri-Sampierdarena Sorting is a double line.
As far as regards the railway lines, they are characterized by different features:

1. the Genoa-Arquata-Alessandria line (even tract) is 75 km long, it has a nearly completely electrified double route and it is utilized for train circulation during the whole day. For the single track line, that ends between Arquata and Ronco, short free periods for train maintenance are foreseen. The tract between Genoa and Arquata supports freight flows going both to Alessandria and Milan and, having a slope up to 35%, a reduction of the trained weight is imposed.
2. the Genoa-Ovada-Alessandria line (odd tract) is 86 km long, completely electrified, with a single line and it is available during the whole day except from short interruptions. Weight limitations are imposed in a tract that connects this line with Voltri Mare station.

A study carried by the railway infrastructure manager has highlighted that there are 40 residual routes for Ovada line and 150 for Arquata one.
The main purpose of this research is to evaluate the port-dry port system through two different scenarios, and utilizing an Event Discrete Simulation model supported by Arena software.
The first scenario considers, as dry port, the existing Alessandria Sorting station area, which is provided with 2 lines for loading/unloading cargo from shuttle trains to and from Genoa, plus two more lines for the block trains composition. Moreover the locomotive changing should occur at the entrance of the station without getting the loading line free.
The second scenario prefigures 3 loading/unloading lines with an average speed of 30 minutes/train despite the 120 minutes/train of the first scenario. Besides the locomotive changing takes place in an external area not interfering with the loading/unloading operations.
Different simulations have been launched varying the number of routes in both directions, terminal capacities, the number of loading/unloading lines in the dry port, the loading/unloading time in the dry port, the shunting and brakes control operative model and the available lines in the Voltri station.
The research goal is to find out which scenario allows the best performance of the port-dry port system in terms of number of trains per day and operative model per day so to increase the competitiveness of the Genoa Port in the national and international context.

II. THE MODEL AND ITS BASIC LOGIC

In order to facilitate the construction of the model and its testing, the initial system has been divided in three different sub models (Genoa Port, railway lines, Dry port).
As shown in figure 2 in total it has been identified eight different sub-systems that represent the logic of the model:

1. Genoa Port – Sech
2. Genoa Port – Messina
3. Genoa Port – VTE
4. Genoa Port – Arrival logic
5. Railway Line – Genoa-Alessandria
6. Railway Line – Alessandria-Genoa
7. Dry Port – Arrival Logic
8. Dry Port – Dry port.

A suitable database has been created utilizing MySQL DBMS in order to be able to manage the simulation outputs in a more flexible and deep way.

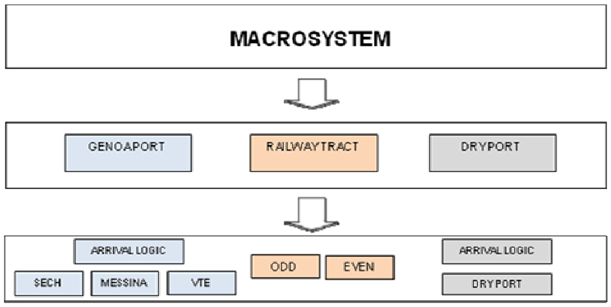


Fig.2 Logical sub models

Actually, in order to better fit with the simulation requirements, the eight logical subsystems have been manipulated: some of them have been further divided, some have been merged and other remained as before.
The nine finale sub models, whose logic is shown in figure 3 and better explained later in the paper, are the following:

1. Arrival and selection in Genoa Port;
2. Sech-Messina terminals;
3. VTE terminal;
4. Campasso;
5. Sampierdarena Sorting;
6. Voltri Mare;
7. Railway section;
8. Alessandria Sorting;
9. Arrival and selection in Alessandria.

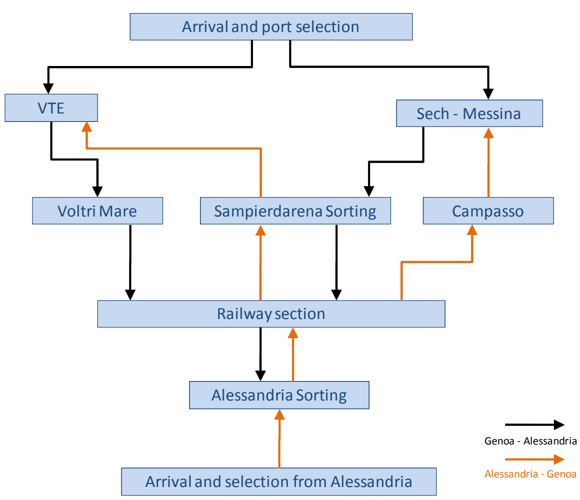
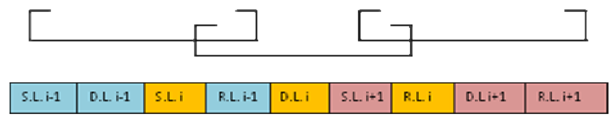


Fig.3 Sub models and their logic

As explained before, the model has two different flows of entities that are moving into the system: from Genoa port to Alessandria and from Alessandria to Genoa port. Entities, from their introduction in the Arena model, will be manipulated and transformed from ship to container, to diesel train, to electric train, then again to diesel train, and finally to container.
The part of the model regarding the "port-railway section" connection has been represented as a group of resources that can be occupied according to the availability of the free lines. The release of the occupied tract for the next train occurs only after that the previous train has gone through the tract and after that the tract has been re-assigned (figure 4).



S.L. = Tract Seize
D.L .= i-th Tract Delay
R.L. = i-th Tract Release

Fig.4 Railway tracts assignment and release sequence

It is important to underlie that among the various simplifications that have been made on the model, the main one is represented by infinite buffers utilized in the railway tract representation, as shown in figure 5.

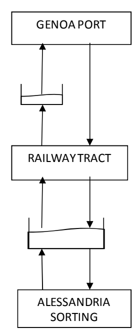


Fig.5 System's buffers

The railway section sub model calculates the tract lead time letting pass the train entity at the time scheduled. The railway section is a kind of black box, with a certain capacity but not able to be questioned on which specific point on the rail an entity is at a certain time. This implies a restriction on the implications of an eventual queue from upstream to downstream. In reality, if a unexpected queue has been created between Alessandria station and the dry port station or between Campasso and Genoa port, trains arriving would suffer a delay in the various intermediate stations between the two stations; the black-box can't "hear" this delay.

Another simplification regards personnel shifts: it has been assumed that there are 24 hours worked on 7 weekdays.

The following paragraphs will explain the logics at the basis of the nine sub models identified.

Arrival and selection in Genoa Port

This sub model is the heart of the ships' arrivals. It has the duty of creating entities by reading data from the database and forwarding them in the respective terminal of destination (Sech, Messina or VTE).

Arrival and selection from Alessandria

This sub model presents 3 entities creation blocks with the role of inserting at each time interval a certain amount of entities in the simulation (with the command Time Between Arrival). After that entities will pass through a module that will assign them an attribute, then they will pass through the container counting and an ID number will be assigned to them (that is the same ID number of Genoa arrivals because the container ID must be unique). After having been divided by destination, entities will be sorted towards Alessandria Sorting sub model.

Sech-Messina Terminal-VTE terminals- Alessandria Sorting

These two sub models gather together the functioning logics of containers loading/unloading and of trains departure/arrival.

Let's consider, for instance, a container train that must be composed in Sech terminal. When the first loading line is available, the trains start to be formed, container after container and, after customs procedures are performed, a diesel locomotive is assigned and jointed to the train. After the brakes check, the train has to wait for a diesel railway line to be available and then it can leave the terminal.

This logic is analogous for Messina and VTE terminals and for Alessandria Sorting as well.

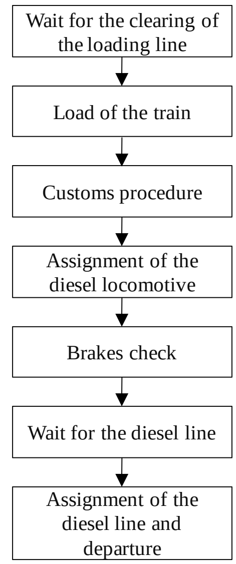


Fig.6 Process of activities in a port or dry port terminal

The entities which pass through these sub-models in order to be sent outside the terminals go across three main phases: waiting, loading and departure. The passage from a phase to another is spaced by events registration.
The passage from containers to trains occurs through the use of a batch module set to 39 units (each train is composed by 39 containers): until 39 entities aren't arrived, no train can leave the terminal. This constraint s posed in order to have only full trains with the same length: in this way advantages in terms of total costs and organization are gained.

Railway section

The railway section is mainly divided in two parts: the first for even trains coming from Sech or Messina through Borzoli to Alessandria; the second for trains coming from VTE to Voltri Mare – Alessandria. For odd trains directed to Sech and Messina it simulates the return from Alessandria to Campasso, while for trains to VTE it is considered the way from Alessandria to Sampierdarena Sorting (via Arquata).

Sampierdarena Sorting-Campasso-Voltri Mare

Figure 7 explains the process flow of activities performed in a connection railway terminal, whatever it is: Sampierdarena Sorting, Campasso, or Voltri Mare.

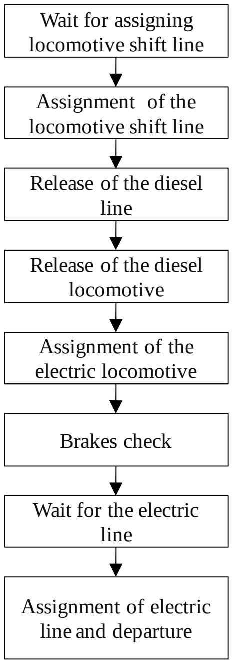


Fig.7 Process of activities in a connection railway terminal

If we consider for instance the case in which a train come from Messina Terminal and it arrives, through a railway diesel line, in Sampierdarena Sorting. First the train will have to wait for a locomotive shift line to be available and assigned; after that the diesel locomotive is released and an electrical locomotive is assigned. At this point the train is ready to undergo the brakes check for being ready to leave the railway terminal.
The case in which the terminal comes from the railway electric line and goes to a port or dry port terminal is analogous to the one that has been just explained.

III. VERIFICATION, VALIDATION AND TESTING

The model verification has been made through the initial analysis of the sub models and later through the analysis of their union. The model validation has been made only on the sub models and not on the global one: a reason for that was the non-existence of the dry port.
Other problems encountered in the model validation and verification have been the lack of some historical data on railway containers traffic in the different terminals and the lack of information regarding the existing traffic on the line.
During the model's coding several aspects (timing, control of elements, control of routes, control logic) have been checked.

Finally model animation has been used to watch how the elements' behaviour was far from both the model logic and the real world.

IV. RESULTS

After the model testing, the study of the system has been divided in two phases: the first regards the analysis of two hypothetical scenarios (A and B), while in the second phase experimental design techniques and neural networks have been utilized to find the response surface.

Phase 1 – Hypothetical scenarios

SCENARIO A

The first scenario had the goal of finding out the system potentiality in terms of number of trains per day.
A basic assumption has been made: the number of diesel and electrical locomotives is infinite.
A scenario is characterized by the following features:

- data of containers' arrival equal to 2004 Genoa port rectified data;
- dry port in Alessandria Sorting;
- 39 Genoa-Ovada-Alessandria railway routes (20 in VTE direction and 19 towards Sech and Messina);
- 42 Alessandria-Arquata-Genoa railway routes;
- Campasso, Voltri and Sampierdarena Sorting are dedicated routes;
- Constant dwell times.

First it has been determined the optimal run time, that resulted in a Mspe of 99 days.
In order to evaluate the system saturation, a route saturation index, calculated with the following formula, has been introduced:

$$S_j = \frac{n_k}{t_j}$$

where:

- S = saturation index of the j-th railway tract;
- n = average number of trains daily passed in the k-th railway tract;
- t = number of available railway routes in the j-th railway tract;
- k = railway area taken into consideration;
- j = railway tract.

According to the number of trains arrived, the saturation index resulted to be equal to 0,27 for the even railway tract (Alessandria as destination) and 0,25 for the odd one (Genoa as destination). This is fairly far from the system saturation (see Table 1).

TABLE I
SATURATION INDEX

	Even railway tracks	Odd railway tracks	Total tracks
# available railway tracks	39	42	81
Saturation index	0,27	0,25	0,26

Alessandria dry port, if identified with the current Alessandria Sorting, has been recognized as the most evident bottleneck of the system.

As a matter of fact the system that has been here considered presents infinite buffers: this implies the formation of unrealistic queues because entities' generators keep creating new entities independently from the downstream capacity, with a resulting increase in the buffers' levels. As a matter of fact the gap between the sum of trains to be loaded and the sum of trains to be unloaded can be seen in the graph in figure 8.

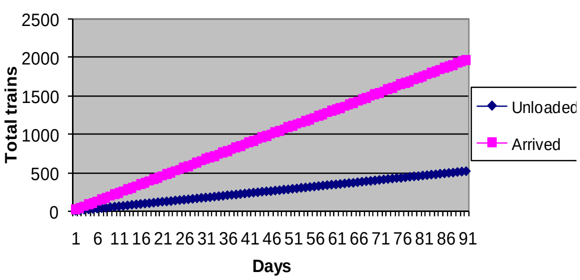


Fig.8 Gaps between trains arrived and trains unloaded in Alessandria

In order to move the queues in other part of the system, an objective function has been studied as a linear combination between the number of trains arrived and the number of unloaded trains in Alessandria.

$$FO = \frac{k_1 * N_t}{t_t} + \frac{k_2 * T_t}{t_t}$$

where:

N_i = number of entities in queue at time t_i;
T_i = time in queue for an entity at time t_i;
K_i = weight related to the parameter.

To study the objective function, loading and unloading times have been changed few times, as well as the number of available resources to unload containers.

The regression surface build (fig.9) has shown a "fall" in the objective function. This means that even if the unloading power in Alessandria Sorting is increased, a bigger number of trains cannot be disposed because the bottleneck moves in another part of the system.

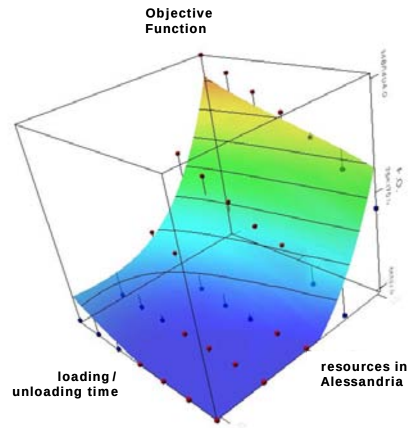


Fig. 9 Regression surface

Two more constraints of this scenario are the shunting for the locomotive's change and the brakes' verification. In fact they block the flows of entities entering and leaving, so increasing the time spent inside the dry port.

SCENARIO B

The second configuration of the system that has been considered is the following:

- data of containers' arrivals equal to 2004 Genoa port rectified data;
- a new dry port: 3 unloading lines with an unloading speed equal to 30 minutes;
- <u>scenario B.a</u>: 39 Genoa-Ovada-Alessandria railway routes (28 in VTE direction, 11 to Sech and Messina). <u>Scenario B.a</u>: 42 Genoa-Ovada-Alessandria railway routes (28 in VTE direction, 14 to Sech and Messina).
- 42 Alessandria-Arquata-Genoa railway routes (28 for VTE and 14 for Sech);
- dedicated routes to Voltri Mare are increased up to 7;
- VTE implemented power from 800 TEU/day to 2200 TEU/day;
- <u>scenario B.a</u>: brake check is performed without freeing the loading line. <u>Scenario B.b</u>: brake check is performed in an external area with unlimited capacity;
- constant dwell times.

The goal of this second scenario has been to control the capacities inside the various segments.
Two sub scenarios (B.a and B.b) have been simulated and the following results are hereafter presented.
In the sub scenario B.a it has been noticed that Alessandria capacity would be equal to 33 trains /day in both directions. As a matter of fact it has been observed that in the even tract (from Genoa to Alessandria) an average of 13-14 trains/day arrived in Campasso, but then they were not all shipped by Sech and Messina terminals (only 40%, that means around 6 trains/day). Recalibrating the % of trains entering the dry port in Genoa direction, and being the VTE capacity not completely exploited, it can be said that the number of trains can reach the value of 33 trains/day, and so the saturation index can increase (as shown in table 2).
In the scenario B.b the dry port would be able to saturate all the routes except from Sech and Messina terminals which showed a saturation index of 0,6. Only calibrating trains arrival in Alessandria is possible to obtain a higher saturation index equal to 0.8, as shown in table 2.

TABLE II

SATURATION INDEX FOR SUB SCENARIO B.A AND B.B (CORRECTED)

	Sub scenario B.a		
	Even railway tracks	Odd railway tracks	Total tracks
# available railway tracks	39	42	81
Saturation index	0,8	0,79	0,82
	Sub scenario B.b		
	Sech+Messina railway tracks	VTE railway tracks	Total tracks
# available railway tracks	28	56	84
Saturation index	0,8	0,98	0,93

Phase 1 – Experimental design and neural networks

After having conducted focused experiments, the system has been analyzed utilizing experimental design techniques (Design of experiments –DOE) and neural networks.
Two are were the main goals of this phase: to study the behaviour of the system, and to evaluate if, with a predetermined increase of the capacity of the different areas, a saturation of all the railway routes occurs.
First, it has been decided which were the most suitable factors to consider. Taken into consideration the results obtained in the previous analysis, it has been decided to investigate in a deeper way the most critical areas: Sech terminal, Messina terminal and Campasso railway connection terminal. Voltri has been added as a factor, in respect to the high number of trains that pass through it.

Once having chosen the parameters, the relative following “low” and “high” levels have been defined:

1. Sech unloading speed: 100%/140%
2. Messina loading /unloading speed 100%/140%
3. Campasso availables lines 4/8
4. Voltri Mare available lines 4/8

As far as regards the objective function, it has been decided to utilize the previous one, expressing the average sum of trains daily unloaded in both directions (dividing the objective function by the number of available routes, the global saturation index of the two tracts is obtained).

Previously in the paper it has been stated that, in order to control the number of trains that arrive to a specific terminal, the relative number of arrivals has been recalibrated. In order to address a correct percentage of containers in a particular terminal, a simple and effective methodology has been studied.
The loading and unloading time in the considered terminal have been represented with two variables (x), which have been inputted in the corresponding Arena process module.
In the “create” block of the Arena model (Arriving and selection from Alessandria) in which there are created all the entities that go to the corresponding terminal, it has been introduced a function that takes into consideration the potentiality and capacity of the three terminals:

$$TBA_i = f\left(\frac{x_i}{x_i + x_j + x_k}\right)$$

where i,j,k represent the three terminal.

Varying in input the terminal capacity, TBA varies. In this way we created an arrival frequency equal to the terminal potentiality and, as a consequence, there is a correct introduction of entities in the process loading queue of the dryport.
The effective simulated time has been of about 42 hours per computer (that means 48 hours in total). The experiment utilized has been a RSM CCD. The experiments framework is shown in attachment 1.

In order to execute the Design Of Experiment, Stat Ease® software has been utilized. Figure 10 shows the results given by the software for the choice of the appropriate regression model: it emerges that the best model to use is the second order model.

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Linear	39.04	18	2.17	5.60	0.0209	Suggested
2FI	33.17	12	2.76	7.13	0.0123	
Quadratic	15.91	8	1.99	5.13	0.0307	Suggested
Cubic	0.000	0				Aliased
Pure Error	2.33	6	0.39			

"Lack of Fit Tests": Want the selected model to have insignificant lack-of-fit.

Model Summary Statistics

Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	1.31	0.4826	0.3964	0.2112	63.07	Suggested
2FI	1.40	0.5561	0.3095	0.0028	79.73	
Quadratic	1.14	0.7719	0.5438	-0.4459	115.61	Suggested
Cubic	0.62	0.9709	0.8643		+	Aliased

+ Case(s) with leverage of 1.0000: PRESS statistic not defined

Fig.10 Choice of the regression model

ANOVA for Response Surface Quadratic Model

Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	61.72	14	4.41	3.38	0.0147	significant
A-Sech	*14.50*	*1*	*14.50*	*11.13*	*0.0049*	
B-Messina	*17.97*	*1*	*17.97*	*13.80*	*0.0023*	
C-Campasso	*0.92*	*1*	*0.92*	*0.71*	*0.4141*	
D-Voltri	*10.05*	*1*	*10.05*	*7.72*	*0.0148*	
AB	*2.84*	*1*	*2.84*	*2.18*	*0.1621*	
AC	*0.26*	*1*	*0.26*	*0.20*	*0.6633*	
AD	*0.77*	*1*	*0.77*	*0.59*	*0.4537*	
BC	*0.71*	*1*	*0.71*	*0.54*	*0.4728*	
BD	*0.26*	*1*	*0.26*	*0.20*	*0.6614*	
CD	*0.24*	*1*	*0.24*	*0.18*	*0.6774*	
A^2	*1.11*	*1*	*1.11*	*0.85*	*0.3726*	
B^2	*0.20*	*1*	*0.20*	*0.15*	*0.7041*	
C^2	*0.27*	*1*	*0.27*	*0.21*	*0.6547*	
D^2	*12.98*	*1*	*12.98*	*9.96*	*0.0070*	
Residual	18.24	14	1.30			
Lack of Fit	*15.91*	*8*	*1.99*	*5.13*	*0.0307*	*significant*
Pure Error	*2.33*	*6*	*0.39*			
Cor Total	79.96	28				

Std. Dev.	1.14	R-Squared	0.7719
Mean	80.40	Adj R-Squared	0.5438
C.V. %	1.42	Pred R-Squared	-0.4459
PRESS	115.61	Adeq Precision	8.189

Fig. 11 ANOVA – Analysis of Variance

Utilizing the second order model of the analysis of variance (figure 11), it can be noticed that F test is successful and this means that the regression is meaningful.

In particular, looking at R2 coefficient, we find out that the model well explains the 77% of data variation. Unluckily, the negative value of "predicted R2" says that the global average predicts the answer better than the actual model. The lack of fit test resulted to be meaningful and this signifies that there is lack of fit, so the model has to be rejected.

The polynomial second order model is the best among the ones that have been tested but, not having overcome the test of fit, it has been decided to utilize a more powerful and flexible tool as the neural networks.

The neural network regression model has been obtained utilizing the 93% of data for the neurons training and the remaining 7% for the model validation. The number of neurons is equal to 6: 4 of input 2 in the hidden layer while 1 of output in the final layer. The training lasted 500000 cycles and the error between the obtained and forecast result has been very low.

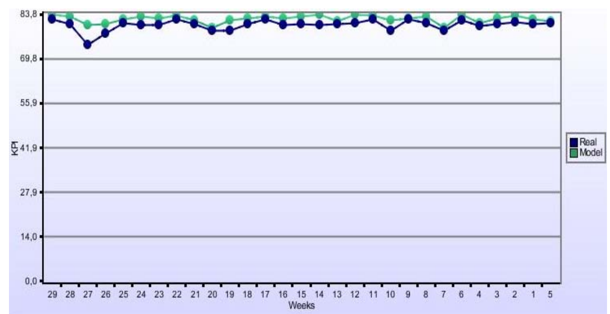


Fig.12 Fitting of the neural model (green) in respect to the real data (blue)

The following figures show the global routes index saturation as a function of the chosen parameters.

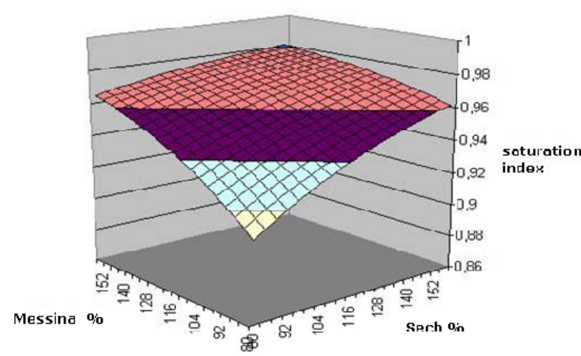


Fig.13 Sech versus Messina

As easy to predict, an increase in the unloading speeds makes the routes saturation index increase.

As is possible to note the Messina Terminal global unloading rate is higher than the Sech one.

With an increase of 50% of the terminal potentiality, the total routes saturation is reached.

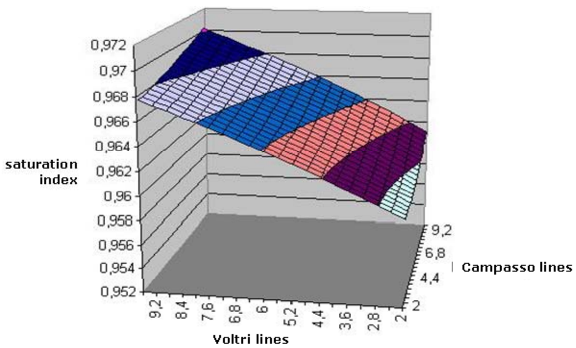


Fig.14 Voltri versus Campasso

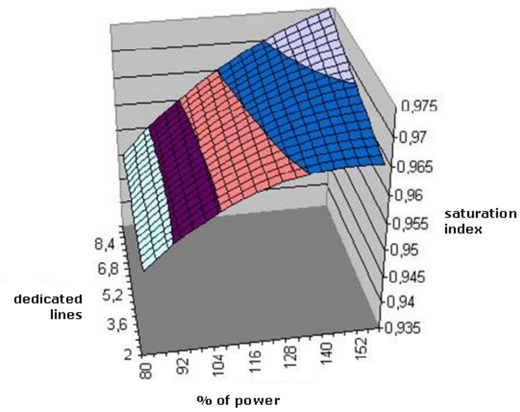


Fig.15 Sech versus Campasso

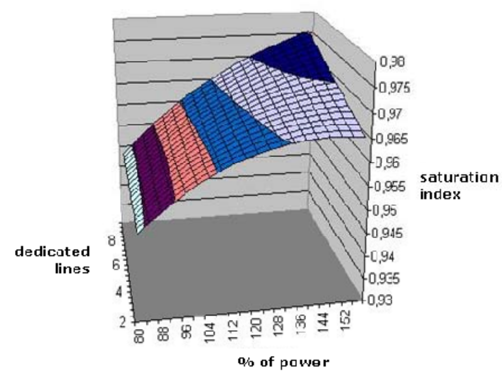


Fig.16 Messina versus Campasso

In figure 14 it can be seen how the overall influence of Voltri station is higher than Campasso one. This is due to the fact that, under the hypothesis of always available lines, Voltri is affected by more than double traffic flow than Campasso. Besides, in the experimental campaign, as far as regards Voltri, we simulated up to the lower bound of 2 lines. In that case the number of trains dramatically decreased (74,3 even if Sech e Messina were at 120%). Looking at the fitting graph of the neural model it can be noticed that the model well explained all the points except the third one (on the x-axis weeks is equal to 27): neurons have smoothed that effect.

After another simulation launch it has been noticed that in those conditions, the decrease obtained was not by chance. The regression objective is to watch how the objective function behave in a particular domain. The execution of a regression with discrete parameters (i.e. available traces) is a forcing because the objective function is discrete along that parameter, even if, in a general context, it can be a good method to better visualize the results. Unfortunately in this case, the shifting from 3 to 2 dedicated lines had a very negative effect on the system. If hypothetically it could be possible to look at the “real” objective function, a very stressed slope would appear (in practise an angle point).

So we can conclude that the regression is not able to explain what happens when the dedicated lines are among two and three. Moreover, even if the function increases with the increasing of the number of Voltri lines, the % saturation gain is very low (about 1%), that means no additional routes.

Utilizing the graphs in figures 15 and 16 the influences of Sech terminal and Messina terminals can be compared with the one of Campasso.

From the gradient analysis it can be seen that Campasso has a lower influence in respect to the unloading speed in the terminals. The graphs in figures 15 and 16 show that increasing the potentiality of the two terminal there is a minor increase in the routes saturation in respect to the decrease of Campasso dedicated lines.

This could mean that for a complete routes saturation Campasso doesn’t influence so much, unless the traffic increases a lot. However it must be underlined that this consideration regards only a trend in the surface and a variation of only 1%. As a matter of fact, being a macroscopic model, it can be affected by a background noise.

Making a comparison of the two projects, it emerges that B is better than A.

As a matter of fact considering project A and assuming an average number of daily trains equal to 21, the maximum quantity that can be handled is 300000 TEUs/year. Project B (which is characterized by an increase of VTE potentiality), having a higher degree of

routes saturation, can instead manage up to 1100000 TEUs/year.
Moreover, during the simulation Voltri lines have been utilized as fully dedicated lines for shuttle trains. In case the available lines were less than 4 (so the saturation index decreases) and assuming that another line is utilized for blocked trains, it is believed that Voltri station will need an enlargement.

V. CONCLUSIONS

The simulation model here proposed has been utilized as an effective tool for the macroscopic verification of the railway flows between Genoa Port and an hypothetical dry port in Alessandria. The model succeeded in identifying the critical areas according to the different simulated scenarios.
The simulation has highlighted the importance of creating an area outside the dry port where executing the shunting of locomotive changing without affecting the downstream from the loading line (scenario A).
Besides it has allowed to focus the attention on particular areas (above all Sech and Messina terminals) according to the scenario utilized.
Thanks to DOE and neural networks it emerged that scenario B is better than A, both in term of mean result and robustness.
Finally another goal has been achieved: the implemented integration between MySQL database and Arena simulation software permitted to have a real basis for the management of arrivals in Genoa port. Besides it allowed to improve input data management and to obtain a more precise output data management.

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ATTACHMENT 1 – TABLE OF CCD EXPERIMENTS

Std	Run	Type	Factor 1 A: Sech %	Factor 2 B: Messina%	Factor 3 C: Campasso available lines	Factor 4 D: Voltri available lines	Response 1 Objective Function
11	1	Fact	100.000	140.000	4.00	4.00	80.7273
12	2	Fact	140.000	140.000	4.00	4.00	81.2626
22	3	Axial	120.000	120.000	10.00	6.00	80.7879
17	4	Axial	80.000	120.000	6.00	6.00	80.0808
6	5	Fact	140.000	100.000	8.00	4.00	81.101
20	6	Axial	120.000	160.000	6.00	6.00	81.9091
5	7	Fact	100.000	100.000	8.00	4.00	78.4747
14	8	Fact	140.000	100.000	8.00	8.00	81.0101
28	9	Center	120.000	120.000	6.00	6.00	82.0606
13	10	Fact	100.000	100.000	8.00	8.00	78.4343
4	11	Fact	140.000	140.000	4.00	4.00	82.2727
27	12	Center	120.000	120.000	6.00	6.00	81.0404
2	13	Fact	140.000	100.000	4.00	4.00	80.5758
24	14	Axial	120.000	120.000	6.00	10.00	80.4848
15	15	Fact	100.000	140.000	8.00	8.00	80.7576
25	16	Center	120.000	120.000	6.00	6.00	80.4848
10	17	Fact	140.000	100.000	4.00	8.00	82.3232
29	18	Center	120.000	120.000	6.00	6.00	80.6465
9	19	Fact	100.000	100.000	4.00	8.00	78.3636
1	20	Fact	100.000	100.000	4.00	4.00	78.6768
7	21	Fact	100.000	140.000	8.00	4.00	80.8485
18	22	Axial	160.000	120.000	6.00	6.00	82.0707
26	23	Center	120.000	120.000	6.00	6.00	80.4748
21	24	Axial	120.000	120.000	2.00	6.00	80.5253
3	25	Fact	100.000	140.000	4.00	4.00	81.0101
19	26	Axial	120.000	80.000	6.00	6.00	77.8788
23	27	Axial	120.000	120.000	6.00	2.00	74.303
8	28	Fact	140.000	140.000	8.00	4.00	80.6667
16	29	Fact	140.000	140.000	8.00	8.00	82.2525