Using Logistic ReDesigner (Lo.R.D.) Software for Designing and Simulating a Steel Supply Chain

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Abstract: - This paper regards the analysis of the development of a logistics and transportation network concerning a steel plant. The main goal is to search for the best scenario that allows to supply the plant and to distribute all the finished products to final customers in the most efficient way. To this aim, a proper simulation model has been developed and implemented utilizing Logistics Re Designer (Lo. R. D.) software. More specifically, three different transportation networks have been created: two "single" modal choice scenarios - by road or by rail – and an "intermodal" one. Another system variable regards the production capacity of the steel plant: three different types of capacity have been considered; so in total nine scenarios have been taken into consideration. The results obtained indicate that the intermodal solution is the most suitable to be adopted both in terms of total time – and consequently costs - and resources required to perform all the necessary operations. Future research will focus on the improvement of the solution found and on the development of an economical analysis.

Key-Words: - intermodality, supply chain design, simulation, network saturation, steel plant, Lo.R.D. software.

1 Introduction

The management of supply chains regarding steel products is quite complex due to the big volume and weight of goods to be handled and the relative high costs to be sustained. Moreover the particular type of good implies strict rules regarding safety and environmental issues to be followed.

For this reasons, proper simulation analysis can be of help in designing and managing at best these particular types of supply chains, while minimizing related costs and resources utilized.

This work is focused on the design of the entire logistics and transportation network of a steel plant located in Bormida Valley in Liguria Region (Italy). More specifically the network starts from the supply of raw materials in Brazil and ends with the final products distribution to the reference markets of Northern Italy and Northern Europe.

To achieve this goal a model of Ferrania logistics network has been built utilizing Lo.R.D. simulation tool.

In particular, three different types of transportation systems have been defined, together with three kind of the plant production capacity, with the final objective of better understanding which scenario gives the best results in terms of minimum time and costs.

The paper is organized as follows: section 2 regards the formulation of the problem, including all the constraints and peculiarities. In section 3 an analysis of the simulation results obtained for the various scenarios has been carried out. Finally, in section 4 final conclusions are provided, together with future research proposals.

2 Problem formulation and description

The problem here addressed, which represents a preliminary analysis for understanding which is the best logistics solution to implement for this steel plant in the near future, focuses on two main parts: the transportation of coils from Savona port to a hypothetic rolling mill located in the steel plant industrial area, and the distribution of steel finished products from the plant to the Northern Europe and Northern Italy markets.

Obviously, since we are speaking about freight trains carrying slabs of steel weighing 32 tons each, the railway slots for this kind of transportation are provided only by night, when passenger traffic is

very low or even zero along this route.
The railway line between Savona and its hinterland is currently composed of two track lines. It would be possible to add a third one in the short term because the ground has already been prepared for its laying.
The third track line should be very useful in the future because it would allow the railroad becoming more efficient, increasing the number of the trains arriving each night to the milling plant, guaranteeing an easier and more elastic production planning.
In addiction to the difficulties related to the number of tracks and the opening hours for freight trains network, there is also, due to the orographic conformation of the terrain, the issue of the necessary power for the train engine to transport the load to the destination without a hitch.
The trains have to face a hilly area with traits having a high gradient that could represent a big problem if undertaken with an unsuited engine.
This question needs careful consideration because, in the near future, there is the will to seek the approval for carrying loads of sixteen hundred tons along this railroad.
With the data available by now, the persons involved in the work affirm that the best solution for the locomotion is to always have two tenders for cargo able to face difficulties along the route.
In our opinion, even for this trait, several enforcement actions have to be undertaken and, possibly, devoted to optimize the line to make it a functional tool for the chain and not a pejorative constraint for the overall performance of the system.
After this brief survey on the transport network, we pass to shortly describe the characteristics of what will be the heartbeat of our simulation: the Ferrania mill.
However, not only the railway solution has been taken into account, but also the intermodal one (in this specific case, rail and road), being the combined transportation a crucial issue in logistics.
The next subsection depicts how the intermodal transportation works, its main features and when this solution represents an advantage.

2.1 Intermodal Transportation
Intermodal is a type of transfer that uses multiple modes of transport in the path that joins the origin to the destination of cargo, because of geographical conditions or infrastructure, or in order to exploit the potentialities of each specific mode, with the aim of producing the service under more convenient terms in respect to the monomodal solution.
As well explain in [1], intermodality inevitably increases some components of transportation costs like the terminal/node operations cost, that linearly increases with the number of transportation modes utilized (that determines the number of transfers from a mode to another one). Moreover intermodality make increasing some components of the total travel time, connected with the transfer operations. The increase of time, both concerning goods or people, represents also a cost term that, in most cases, is difficult to quantify.
Transfers introduce elements of criticalities: they make the load less reliable or less safe, if compared to single-mode transportation; moreover intermodal nodes constitute elements of comparative vulnerability of the transport system, because they can cause bottlenecks due to nodes congestion.
So, apart from the cases in which intermodality is strictly required due to geographical conditions or the state of the infrastructure, there must be clear and firm benefits able to overcome the negative aspects above mentioned. These benefits derive from the pursuit of the optimal transportation mode and, regarding each mode, from the pursuit of the optimal size and features of the vehicle, in relation to the load volume and characteristics. In fact, a key factor in the choice of intermodality, is the entity of cargo flows: in other words the confluence of different flows in some sections of the network allows to reach significant economies of scale, and so makes intermodality transport convenient. On the contrary, small traffic volumes can impose the choice of different transportation solutions and vehicles.
It is therefore possible to distinguish between two different types of intermodality:

1. "technical" intermodality, due to geographical or structural causes.
2. "economical" intermodality, due to factors of convenience and logistics management that compensate for higher risks and costs arising from cargo transfers.

The increase of economic intermodality in the last thirty years is due to deep changes: the enormous increase in world trade has made possible, in the transportation field, the achievement of previously unthinkable economies of scale, thanks to the increasing size of vehicles, especially in maritime transport, and to the spread of the specialized transportation.
The increase of fixed costs related to transport has been balanced by innovations on loads handling, also resulting from the unification and standardization of loading units, which have permitted to reduce costs, risks and time.
When there are the conditions for economic intermodality, there is an increase of efficiency

given by the difference between the lower travel unit costs per mile and the higher intermodal transfer unit costs, kept relatively low by the standardization; and there is a loss of efficacy provided by the higher load total travel time and the lower transport safety.
So, which are the critical conditions for which intermodal transportation option is more convenient in respect to traditional single mode?
In the case of technical intermodality, there is not a problem of choice and the matter only regards the minimization of costs, delays and risks associated with transfers.
In the case of economical intermodality, in the case of technically the same mean could be used from origin to destination, an intermodal alternative exists if a part of this total distance should be replaced by another mode of transport. This solution is convenient if it allows achieving a benefit that is bigger than the higher costs deriving from the two or more additional transfers.
The graph developed by Hoover in 1948 clearly shows the concepts expressed so far (Figure 1).

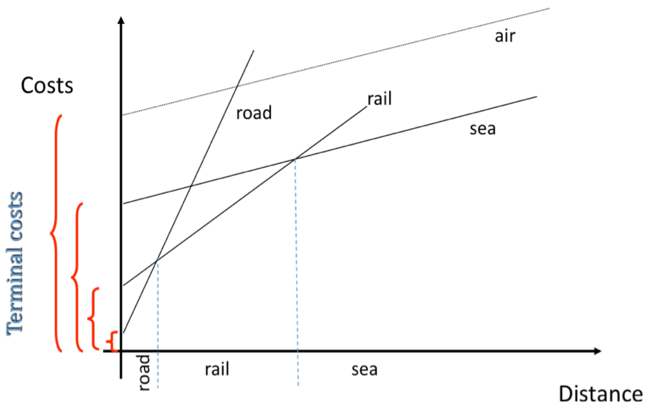

Fig.1 Hoover Graph for transportation costs related to the distance

Inside the economical intermodality framework we can distinguish two more cases:

- the mode of transport with the lowest cost per unit of distance is not available on the entire route so, in order to exploit the economy, it is necessary to organize a complex cycle of transport;
- the various modes of transport involved, including a cheaper one, at least in certain conditions (size, weight, type and load), are available on the whole path, and the intermodal choice is dictated only by the different conditions of demand on the different routes, and by the possibility that the convergence of different traffic flows permits, only on certain sections of the route, economies of scale otherwise impossible.

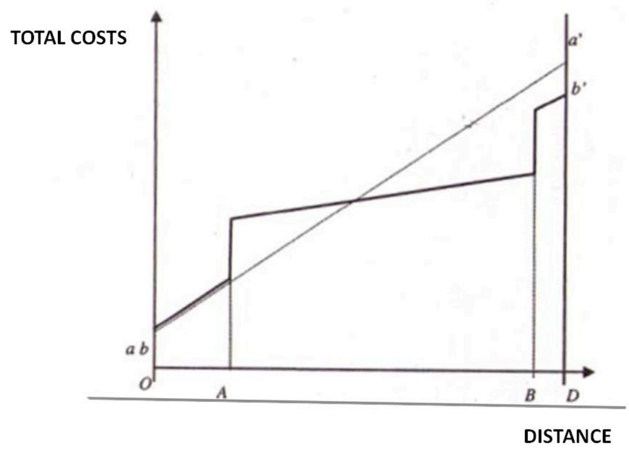

Fig.2 Comparison between truck transportation (a'), and intermodal one(b')

Figure 2 highlights the difference between a single mode transportation utilizing truck (route aa') and an intermodal one that combines rail and road (bb'). This second solution (bb') turns to be more convenient.
On the contrary, there are cases in which the single mode transportation choice is winning, as in Figure 3.

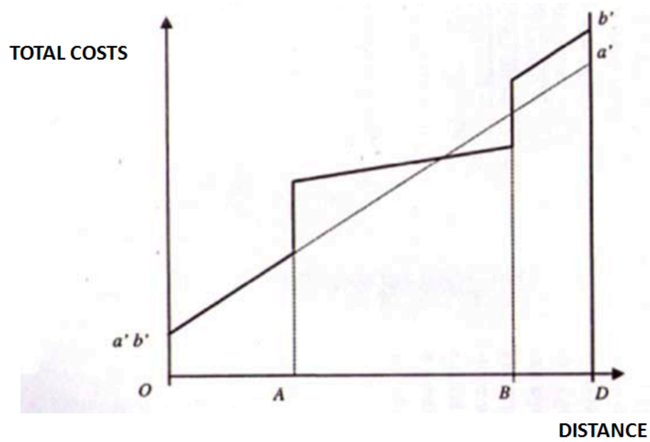

Fig.3 Comparison between single mode truck transportation (a'), and intermodal truck plus railway (b')

In conclusion, the intermodal choice is inside the field of those decisions devoted to the full optimization of the supply chain and, therefore, to the achievement of its greatest efficiency and effectiveness.

2.2 Lo. R. D. Software
LORD is a tool devoted to analyze and simulate a supply chain, suitable both for tactical and strategic

planning.
Unlike traditional simulators, LORD is not bound only to the optimization costs; in fact it allows to optimize according to the most important market objectives: cost, shipments performance and benefits. Logistics operations include not only the distribution but also production.
These options enable the creation of realistic scenarios in the simulator, making the tool a real support for decisions making concerning real strategies.
LORD allows:
• analysis of the structures of alternative distribution channels in terms of cost, time and utilization;
• development of new methodologies for purchasing / inventory and sales policies for existing logistics channels;
• balancing the production and logistics costs;
• seeking solutions devoted to decrease inventory levels without penalizing customer services;
• analyze the effects of a fluctuating demand, frequency of delivery downs, changes in the timing of different operations;
• create distribution segmented strategies for customers;
• maintain partnerships in supply-chains through the establishment of benefits and image return for multiple partners;
• create simulations to motivate the company staff.

2.3 Production data

The data regarding the proposed problem are presented here after.
Assuming that all the quantity produced is sold without any waste, production and sell volumes range from 700.000 tons/year up to 1.500.000 tons/year of finished coil products, according to the different kind of scenario
taken into consideration (Table 1). Two different types of coil are produced: a rougher product (black coil) and a better finished one (pickled coil); each coil roll and each piece of raw material weights 32 tons. It is assumed that there is no transformation of weight in the process from raw materials to finished products. On the contrary, there
is only one type of raw material that comes from Brazil,
the brams.

Table 1. Production volumes according to the different scenarios

Scenario	Production volumes (tons/year)
Scenario 1	700.000
Scenario 2	1.000.000
Scenario 3	1.500.000

Only the pickled coils, that represent 2/3 of the total production volume, will be sold to final customers, while the black ones are shipped back to Savona port in order to be sold in an overseas market.
Finally, there are three eight hours shifts for five days a week.

2.4 From Brazil to Savona

It will now be analyzed the whole logistics network, from the raw materials supply up to the final products distribution.
Raw materials (brams) are shipped to Savona port from a factory located in Brazil, by means of two cargo boats having the features described in Table 2.

Table 2. Cargo boats features

Maximum Load (tons)	184.000
Maximum Load (TEU)	8000
Average Speed (km/h)	40

2.5 From Savona to Ferrania

Once the brams have arrived in Savona, they are shipped to Bormida valley by railway, through the existent railway network connecting the port with its hinterland (Table 3).

Table 3. Savona-Cairo railway network peculiarities

Maximum load per train (tons)	1350
Train shipped daily	3
Number of tracks	2
Distance (km)	22
Average train speed (km/h)	40

As shown in Table 3, being the number of tracks only 2, there is the constraint to ship a maximum of only three trains per day.

There are also problems concerning the maximum weight transportable per cargo because the single vehicle has a load limit of 1350 tons.
Besides, as it can be seen from Fig.4, the territory is quite hostile: slopes imply difficulties in the choice of the right powered engine to bring the train to its destination.

Fig.4 View of the railway path connecting Savona with the Ferrania plant

2.6 Ferrania steel mill

As stated before, this work is a feasibility study to understand which would be the most proper logistics and transportation network to be put into place for the Ferrania steel mill. For its characteristics of space and transportation network connections, the Bormida valley is deemed as a suitable place to build a steel plant.
As specified previously in the paper, the production volumes are raised in three steps according to the specific scenario chosen. Keeping fix the number of production days to be stored in the warehouse, while increasing the quantity of produced good, the warehouse storage capacity will need to be increased as well.
More specifically, varying the production volumes, the dispatch capacity of the plant changes according to formula (1).

$$\textit{Dispatch capacity} = \textit{Production volume (tons)} / \textit{number of days} \quad (1)$$

In Table 4 the warehouses features are presented.

Table 4. Warehouse features

Warehouse	Days of production stored
Black coil	8
Pickled coil	15
Brams	15

The steel mill transforms the brams into two different types of coil rolls: the pickled and the black ones. As previously said, the pickled coil represents the main part
of the daily production (2/3 of entire coils produced per day) and they are the goods that will be sold to customers. On the contrary, black coils are brought back to Savona port.

2.7 Customers

It will now be analyzed the core of the problem, which is represented by the distribution network.
In the model, two different types of customers have been created:

- big customers, characterized by a great number of coils per order;
- small customers, that order small quantities of finished products.

In order to be as much realistic as possible, the main big customers has assumed to be represented by real big customers for the steel market, such as cars company like Volkswagen, Renault, Fiat, Daimler etc.
On the other side, little customers can be represented by small factories with tiny steel needs. Fig.5 shows a LoRD screenshot in which the distribution network is shown, together wih all the customers and facilities.

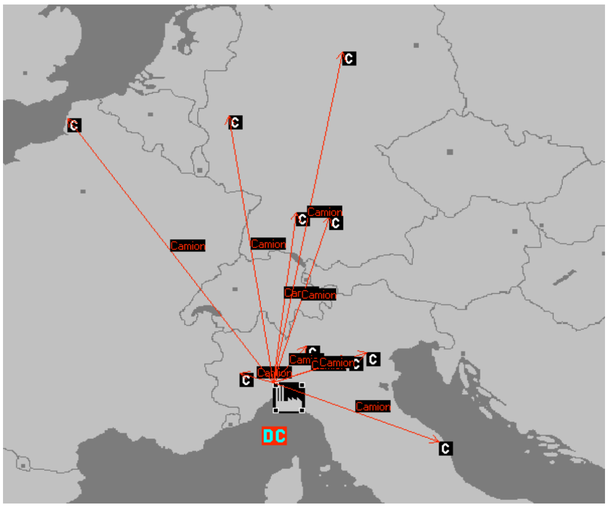

Fig.5 Distribution network in LoRD

For each customer, a specific demand has been set according to the size of its factory. Fig. 6 presents the amounts of orders set for the first production scenario.

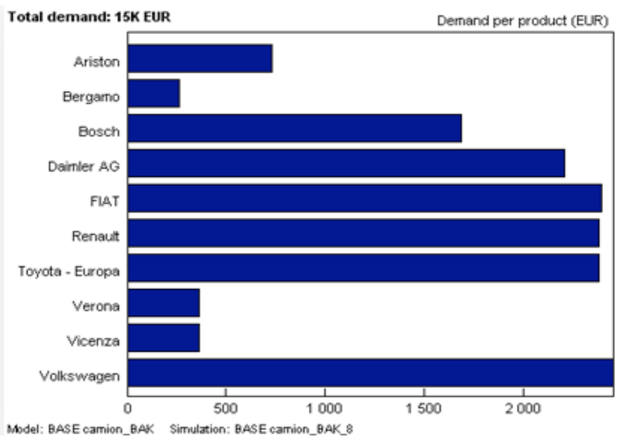

Fig. 6 Customers yearly demand (value)

It is worth underlining again that raising the production, the demand will increase consequently: this means that the market fully absorbs the coil production. As a matter of fact this work is mostly focused on the transportation network and no considerations are made from the economic point of view.

2.8 The logistics networks

In order to find the best transportation system that accomplishes the market needs, the following three network solutions has been created and studied:

1. road network;
2. rail network;
3. intermodal network.

For a matter of brevity, hereafter it will be considered graphs and tables relative to only three of the total links:

- Ferrania – Wolfsburg;
- Ferrania – Torino;
- Ferrania – Bergamo.

Ferrania – Wolfsburg refers to the link of the customer Volkswagen and it represents the most stressed connection in the model. It is also the furthest customer from Ferrania with the biggest orders compared to the other customers; so the data obtained from the analysis of this connection can represent properly all the other big customers' links.
Torino represents an exception among the Northern Italy customers; in fact in terms of orders it behaves as a great customer even if only small factories have been settled in this geographic area. For this reason particular attention will be put on the simulation results obtained for this particular link.
Finally the Ferrania – Bergamo link will be considered as an example of small customers behavior; it is possible to care about just one small customer because all these types
of link have same characteristics (demand pattern, orders volumes, etc.).
So from now on only the results obtained for this three particular links will be taken into consideration.
Tables 5 and 6 present the different features of the road and rail transportation networks. The intermodal network utilizes both road and rail features.

Table 5. The road service

Maximum load per truck (tons)	35
Fleet	unlimited
Maximum driven distance (km)	1581
Avg. Speed (km/h)	40

Table 6. The rail service

Maximum load per train (tons)	1600
Fleet	unlimited
Maximum distance (km)	1581
Avg. speed (km/h)	60

The maximum load per truck is 35 tons: this implies that a vehicle can carry only a single coil.
As said before, the first part of the supply chain – the supply of raw materials by boat and rail – remains inahaltered for each transportation network. Changes will regard only the distribution networks and the production volumes. As a matter of fact, it has been said that for each system three different production volumes have been applied and then it has been analyzed how each network react to them.
Being the attention of the paper directed towards the saturation of the network, the focus is put on the traffic observed on each supply link of the network and on the average number of vehicles used to ship the orders on each link.
In order to collect useful data to perform correct analysis, all the simulations have been launched over a time period of 180 days.

3 Simulation results

This section aims at presenting all the simulation results obtained for the different scenarios previously described.
In the first network model it is assumed that all the orders are managed using only the truck service created with the settings of Table 5.

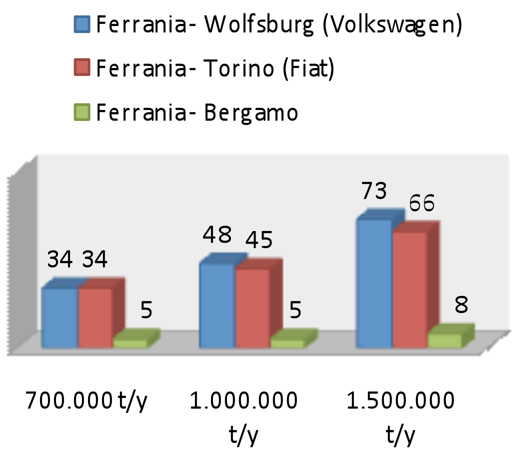

Fig. 7 Trucks per order – "road" network

Fig.7 shows the results obtained after a complete simulation utilizing the "road" network. Looking at the graph, it can be noticed how many vehicles have been used to carry out a single supply mission on the major links of Wolfsburg and Torino (that have Volkswagen and Fiat as customers, respectively). Starting with 34 trucks for the first scenario the number of trucks increases to 48-45 for the second scenario and reaches the values of 73-66 in the last hypothesis. This implies that the links connecting Ferrania to big customers are very close to saturation, because of the big quantity of vehicles per single order.
On the other hand, orders concerning small customers, such as Bergamo factory, need a smaller number of trucks to be managed in all the three production scenarios.

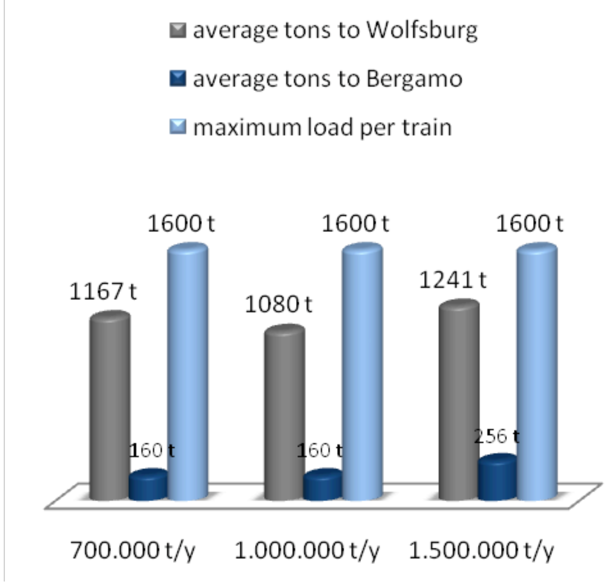

Fig.8 Real vs maximum load per train

In the second network all the customers links are served by rail. The greater maximum load per vehicle given by the railway mode – 1600 tons per each train against 35 tons per single truck – relieves the pressure on the links even if big orders of goods have to be managed, as it can be seen comparing Fig.6 with Table 7. However in the "rail" network, some problems appear for small links. Fig.8 shows that each order directed to one of the smaller Northern Italian clients, such as Bergamo, is just 10% fully loaded. This represents a big lack of efficiency in the orders management and, in other words, a big waste of resources with a consequent increase of the total costs.

Table 7. Trains per order on different links

Scenario (tons/year)	Ferrania - Bergamo	Ferrania - Wolfsburg	Ferrania – Torino
700.000	1	1	1
1.000.000	1	1,5	1,5
1.500.000	1	2	2

So, it can be stated that this second type of network appears to be suitable for handling big customers needs, which order big quantity of coils so allowing to better exploit the train capacity. On the other hand, for little customers the railway network results to be not appropriate because of the lack of train saturation.

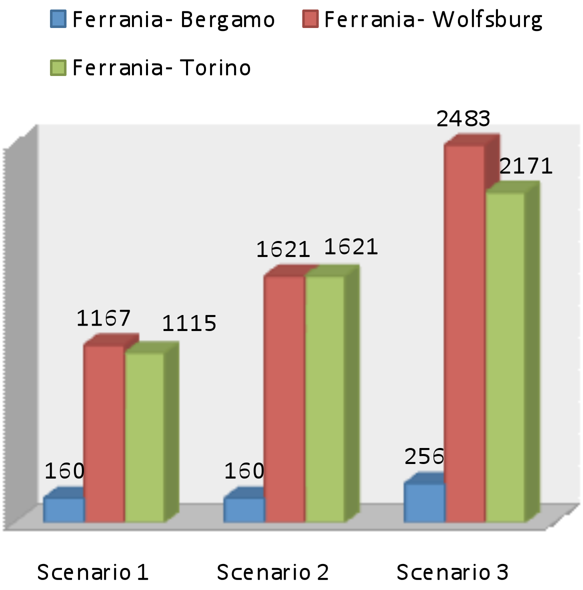

Fig. 9 Average tons per order on the different links for the different scenarios – "rail" network

Fig.9 puts into evidence the tons per order and per link carried in the "rail" network.
Unluckily none of the previous two options completely fulfill the logistics and transportation needs of Ferrania plant; so an "intermodal" network has been built, as a
combination of the previous ones. In the intermodal case a new structure has been created: the Munich hub, in which the switch from road to rail modality is performed. More specifically in this third case the Munich warehouse is supplied by the truck service directly from the Ferrania steel mill and from here final products reach the Northern Europe customers by train. Italian customers continue to be refilled by the road service.
As it happens for the other facilities, the Munich warehouse capacity changes according with the changes in the production settings (Table 8).

Table 8. Munich warehouse storage capacity

Production Scenario (tons/year)	Capacity (tons)
700.000	56640
1.000.000	80640
1.500.000	120960

In Table 9 all the simulation data obtained for Ferrania-Munich road link are presented. This road link presents the same problem seen before for big customers in the road network, even if with a minor impact; fully optimizing this path will be an object of further studies.

Table 9. Data from Ferrania-Munich link

Scenario (tons/year)	Order	Trucks/order	Tons/ order
700.000	130	34	1190
1.000.000	152	48	1668
1.500.000	163	58	2029

Fig. 10 shows which is the number of trucks required for the "intermodal scenario" in the Northern Italy market (Ferrania – Bergamo and Ferrania – Torino links).

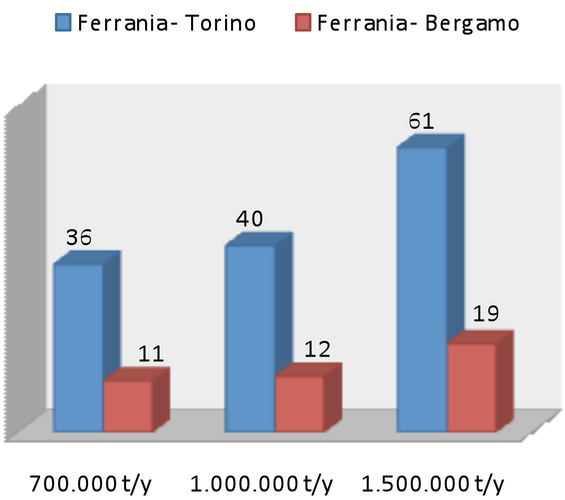

Fig.10 Vehicles per order on Torino and Bergamo links

Fig. 10 shows what happens on the two different road links. The Torino path presents the usual problem of saturation seen in the "road" network for big customers – too many trucks used per single order - and maybe converting the "road" choice into a "rail" one would give better results; for Bergamo's

link instead, the service work properly.
Fig.11 puts into evidence the number of trains used to supply the Wolfsburg customer departing from Monaco hub.

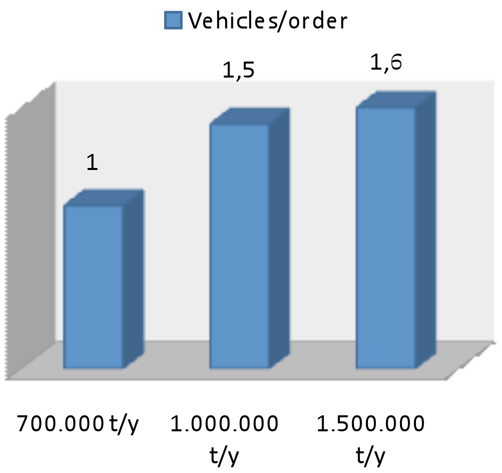

Fig. 11 Vehicles used on the single order on Munich-Wolfsburg

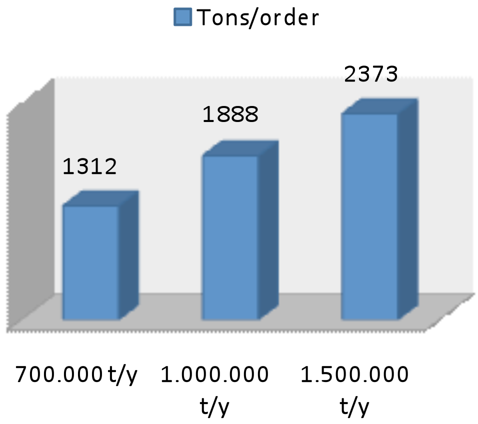

Fig. 12 Tons shipped in a single order on Munich-Wolfsburg

Fig. 12 provides the tons per order shipped from Monaco to Volkswagen in Wolfsburg. The rail solution seems to fit perfectly the needs of a big customer as Wolfsburg. The numbers of vehicles used and the tons shipped per order are far away from the saturation point of the network.
In conclusion, it can be said that the intermodal network appears to be the best network created so far.
The last problem to be solved remains the Ferrania – Munich "road" link, which presents a saturation problem. A possible solution could be to transfer/move some traffic to a second hub which should manage some big clients.
In this hypothetical scenario, not already fully built and analyzed, the new facility would be located in Southern France, near Grenoble, served by road mode – as done for the Ferrania-Munich link – and would supply two of the six big customers. The preliminary effects on the Ferrania – Munich "road" link are illustrated in Fig.13.

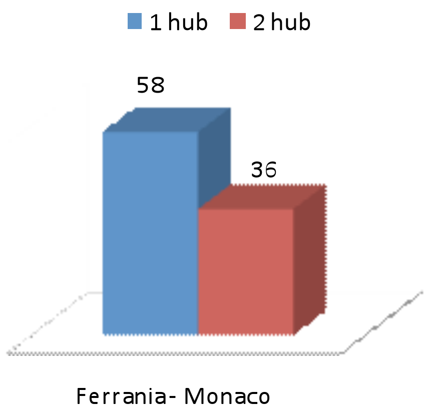

Fig. 13 Trucks per order according to the number of hubs – "intermodal" network

Fig.13 explains how the number of trucks, used on the Munich link, decreases when the Grenoble hub works connected to the Munich's one, giving some breath to the whole network.

4 Conclusion

This work aims at optimizing the logistics and transportation network regarding a steel plant located in the Bormida Valley, in Italy. The analysis embraces the supply of raw materials from Brazil up to the distribution of final products to the Italian and European customers.
Three different network scenarios, according to the transportation modes utilized, have been created and they have been simulated utilizing Lo.R.D software. Moreover, for each transportation scenario three different production volumes have been applied, so creating nine different models to be analyzed.
The simulation results obtained have shown that the single mode networks do not fit totally the needs of the distribution chain. As a matter of fact, the road system very quickly saturate with the raise of the production and too much vehicles and resources are used to fulfill all the orders.
On the other side, the railway network presents a lack of efficiency for the management of small customers' orders: vehicles are loaded only up to

10% of their full capacity.
A third network, the intermodal one, has been modelled in order to try solving the single mode difficulties.
Using the Munich's hub and utilizing the two transportation modes together on different types of link – Northern Italy and Munich are served by road transport
while the rest by train – there is an exploit of the points of strength of each mode and a consequent reduction of waste of resources.
Unfortunately with this configuration some difficulties emerge in relation to the Ferrania – Munich link, where the trucks traffic has to be reduced, especially with the increasing of steel production. A possible solution could be the creation of a second hub. The first results obtained are promising but further analyses have to be performed.
In conclusion it can be said that the intermodal transportation network appears to be the most suitable solution, in terms of order management and network saturation, to support the logistics needs of the Ferrania steel plant.
Future researches will be dedicated to the improvement of the intermodal solution and also to an economic analysis of the system.

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He had a working experience in 2004-2005 with Piaggio Aero Industries, Genoa Plant, for reengineering the productive process of an executive aircraft.
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He also developed Decision Support Systems using System Dynamics for maintenance in the transportation field, in cooperation with some of the most important Italian motorway management companies.
He also developed simulators for vehicular traffic flows using Java™ for several municipalities in northern Italy.
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From 2004 to 2006 she had a working experience in Costa Cruise Company and then she worked in a consulting project for the processes reengineering of an American company.

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Roberto Mosca is Full Professor at the DIPTEM (Department of Industrial Production Engineering, Thermoenergetics and mathematical Models), University of Genoa. He has worked in the simulation sector since 1969 using discrete and stochastic industrial simulators for off-line and on-line applications. His research work focuses on the evaluation of simulation languages and new modeling techniques and his research team is developing new AI applications for industrial plant management. Currently he is involved as coordinator in the coordination of Savona campus, focused on industrial engineering and he is the Director of DIPTEM University of Genoa.

Roberto Revetria earned his degree in mechanical engineering at the University of Genoa and completed his master thesis in Genoa Mass Transportation Company developing an automatic system integrating ANN (Artificial Neural Networks) and simulation with an ERP (Enterprise Resource Planning) for supporting purchasing activities. He had consulting experience in modeling applied to environmental management for the new Bosch plant facility TDI Common Rail Technology in construction near Bari. During his service in the Navy as officer, he was involved in the development of WSS&S (Weapon System Simulation & Service) Project. He completed is PhD in Mechanical Engineering in 2001 defending his Doctoral thesis on “Advances in Industrial Plant Management” by applying Artificial iontelligence and Distributed Simulation to several Industrial Cases. Since 1998 is active in Distributed Simulation by moving US DoD HLA (High Level Architecture) Paradigm from Military to Industrial application. In 2000 he succesfully led a research group first demonstrating practical application of HLA in not dedicated network involving a 8 International University Group. He is currently involved, as reseacher, in the DIPTEM of Genoa University, working on advanced modeling projects for Simulation/ERP integration and DSS/maintenance planning applied to industrial case studies (Contracting & Engineering and Retail companies). He is active in developing projects involving simulation with special attention to Distributed Discrete Event and Agent Based Continuous Simulation (SwarmSimulation Agents). He is teaching Modelling & Simulation, VV&A, Distributed Simulation (HLA), Projecty Management in Master Courses Worldwide and he is teaching Industrial Plants Design and Maintenance Management in University of Genoa Masters' Courses. He is member of SCS, IASTED, ACM, ANIMP, AICE, MIMOS and Liophant Simulation Club. He is Associated Professor in Mechanical Engineering and Logistics.