MODELING AND SIMULATION AS SUPPORT FOR DECISIONS MAKING IN PETROCHEMICAL MARINE LOGISTICS

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Abstract
The paper proposes a simulation model to support decision in marine logistics; the application field is related to petrochemical industry where different production sites need exchange intermediate products by marine lines; the MARLON model and the use of this simulation approach is described and new applications based on distributed use of these innovative decision support system are proposed and demonstrated; in fact an experimental analysis on a case study is proposed as example of the potential provided by MARLON in improving logistics marine solutions within this field;

INTRODUCTION

The market globalization, the arising of new markets like China and Latin America that permit the access to new resources with low pricing policies and the economical world crisis that make a decrementation of the demand in most of western countries causes continuously and very fast changing in world economy. In all the industrial field logistics, and related costs are a relevant importance especially in maritime logistics. For the previous reason and in the scenario characterized by continuously and very fast changes companies must be careful in taking decision involving their supply chain and their logistics solutions; due to the complexity of the real environment simulation is one of the powerful approach to support the DSS (Decision Support Sustem) of that enterprises. The proposed research is focused on petrochemical logistics with special attention to marine operations; the authors present an innovative approach based on Modeling & Simulation (M&S) technique to support decision maker in problem solving related to maritime logistics, especially in fleets management and sequencing of ship missions over a wide set of chemical plants (Bruzzone et al., 2004). The advantages by using simulation for supporting DSS (in order to optimize resource management, time and costs) are highlighted in the paper. The simulation model developed by the authors allows to analyze complex problems affected by stochastic factors and to evaluate alternative solutions related to logistics network management within petrochemical industries. The simulator proposed in this research is defined MARLON (MARitime LOgistic Network). This simulation model is designed in order to support decisions makers, considering stochastic variables (such as weather condition during the navigation, variability in production rates, failures, demand changes etc) that have influence on the whole supply chain; navigation time, load/unload operations time as well as ship fees and missions costs are in fact critical factors to identify optimal solutions over scenarios.

MARINE LOGISTICS

Due to the necessity both to improve customers service, get benefits of global evolving markets and manage the variations in goods flows it is evident the importance of marine logistics and the strategic issue related to the management of related supply chains.

In almost all the industrial sector the importance of that aspect grows very quickly and consequently grows the interest of companies, also petrochemical companies, in R&D (Research and Development) devoted to improve the efficiency and effectiveness of their Supply Chain (Christopher, M., 1998).
The paper, in fact, focuses on the development of a simulation model devoted to provide petrochemical industries with an effective decision support system (DSS) for maritime logistics of liquid bulks (i.e. chemical intermediate products).
The transportation of chemical bulks is often performed by ship in high percentage; despite its flexibility and convenience this transportation solution is affected by a large number of technical (port infrastructure, site tanks) and commercial (contracts, fees…) constraints.
Due to these reasons different major leading companies in this sector are investing in R&D (Research and Development) for improving their logistics networks and their supply chain effectiveness.

CRITICAL ISSUES IN MARINE LOGISTICS

As anticipated the Maritime Transportation is an important way for goods transportation and recently it is increasingly characterized by innovative solutions and technologies to improve customers service and to satisfy their increasing needs. For the transportation of bulk chemical liquids (i.e. petrol) maritime transportation is a very competitive way respect other solutions and sometime even compared to pipelines due to particular advantages in terms of flexibility, safety regulations and laws.
In fact the logistics solution to be chosen for Chemical Bulk depends mainly by two aspects: quantity to be transported and distance to be covered.
This kind of product are made by continuous chemical processes into Chemical Plants; anyway, to avoid stock out and/or stop of production the raw materials supply needs to be managed with particular care.
The percentage of bulk liquid transported every year is the about the 30% of the total weight of materials shipped world-wide. The use of shipping to transport liquid bulk is performed mainly when: is necessary to transport non compatible products, is necessary to cover wide distance; and in addition maritime transportation guarantees more flexibility, independence from territory morphology.
Due to the high number of components, Maritime Network is a very complex System including harbors, ports and intermodal connections and infrastructures (pumps, tanks, docks and plants) and it is characterized by several stochastic variables that make complex flows and resources management.
Some critical point are:

- Legislative constraints about quantities, not allowed products, not allowed areas for navigation
- Compatibility of Transported Products, from a space point of view (it is not possible to mix into the same tank two different products) and time point of view (i.e. tank cleaning operations to transport a different product)
- Stochastic factors: models able to fit this real complex environment should take care of the stochastic factors. In this case for marine side there are ship fees, weather and sea conditions that influence navigation time and load and unload operations or presence of other ships that could slow down port operations; therefore demand behavior, product prices evolution and production site productivity represent other major context for stochastic factors

Due to high complexity of the systems reproduce is necessary to consider some additional parameters:

- Distance to be covered
- Sequence of port in complex missions (that's very critical during the planning phase because)
- Transported material quantities that influence the time of navigation and of the operations in the port.
- Availability of the ships used for transportation
- Type of ship
- Ship Capability

Safety issue due to the characteristics of the liquid transported are critical and have a large impact on almost all the item involved in the transportation (i.e. plants and infrastructures are designed in order to respect all fire laws).
One of the main goal of companies is to is to maintain active the process and guarantee the production by supplying right quantities at the right time and in the right way and by reducing costs with a correct fleet configuration and an efficient planning and scheduling of paths and missions.
The high variability in ship fees over different contract times

M&S BENEFITS IN PETROCHEMICAL LOGISTIC NETWORK

There are several ways to optimise Marine Chemical Bulk Transportation, and due to the not-linear nature of this problem and to the strong mutual influence of variables and the presence of many important stochastic elements it is usually necessary to introduce simulation models as decision support system.

In fact in order to reduce costs and increase the plant production, especially considering that chemical plants are generally operative 24 hours/day, 7 days/week, is necessary an appropriate logistics management system able to react dynamically to market changes (i.e. product prices and ship fees).
Obviously the prohibitive costs of production stops due to the continuous nature of these processes and the strongly economic involvement of even operating chemical plants out of their optimal operative range it becomes very critical to guarantee a robust logistics solutions; this in fact is connected not only to the direct costs, but even to technical problems (i.e. damage to the reactors, long time for the start up); so it is evident that this kind of process requires a reliable and regular flow of supplying and also a available storage for chemical reaction products; therefore it's very critical to design appropriate inventory management systems to guarantee the process continuity (Longo et al. 2009).

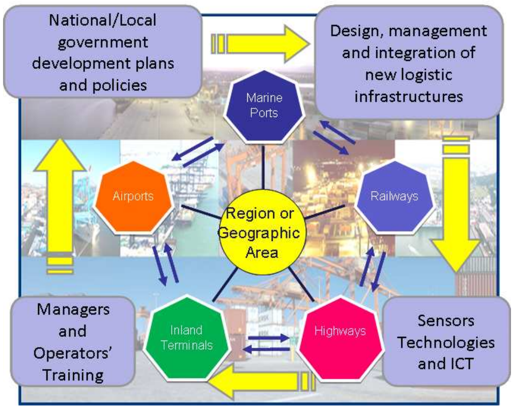


Figure 1. Logistic Network Model

The following aspects characterize the logistic networks in petrochemical field:

- Integration of Complex Systems
- Different Operations in different nodes
- Analytical approaches rarely succeed in properly identifying optimal solutions
- M&S (Modeling & Simulation) is necessary due to the Complexity and Interactions among the networks.
- Variables and Stochastic factors interact and dynamically evolve in time, space in the entire network

Figure 1 shows the benefits provided by using simulation as support to different functions in a marine logistic network:

- Managers and operators training:
  - Training made by quantitative models and innovative approaches.
  - Special high education processes on complex systems life cycle management
  - Personnel evaluation and Recruitment procedures based on realistic, immersive and challenging scenarios
- Government laws and policies:
  - Improvement and evaluation of actual supply chain efficiency and competitiveness
  - Impacts of normative and laws
  - Costs/revenues analysis
  - Point of contact between public and private logistics
- Sensors Technologies and ICT
  - Evaluation of available Sensors and IT solutions
  - Definition of Technical requirements
  - Evaluation of data/information management solutions and ICT tools
- Design, management and integration of new logistic infrastructures
  - Optimization of Demand Production Flows
  - Improvements of marine terminal infrastructures
  - Optimal Reallocation for production site tank infrastructures
  - Enhancement of marine ports services
  - Analysis of Logistics & Transportation scenario
  - Positioning optimization for production sites

As anticipated this research is focused by the authors mainly for marine logistics petrochemical industry:

- Sizing and Fleet management (Sea Logistics)
  - Optimization of Ship Fleet and contracts
  - Scheduling of Ship Operations and extra port activities
- Analysis of Investments on Plants related to their facilities and related marine infrastructures
- The possibility to interact, aided by the integration of the simulator and the web for the all the people involved in the project simulating different scenarios during videoconferences to support the decision making (Information Logistic)
- Management of Ancillary Logistics and Transportation (personnel transportation, support material logistics, Definition of Infrastructure and solutions, Management Optimization Tools)

In fact the author developed the MARLON simulator (www.mastsrl.eu/solutions/marlon) in order to support:

- Evaluation of Ship Costs:
  - Navigation Fuel
  - Port Fuel
  - Ship Daily Costs
  - Extra Costs
  - Total Costs per Mission

- Total Fleet Costs

- Evaluation of Sites Costs for overstock and stock-out occurrences
- Analysis of Current Flows Management
- Analysis of Alternative Scenarios

MARLON: MARITIME LOGISTICS NETWORK

The complex system to be reproduced and analyzed suggest to use simulation; in fact the model developed by the authors consider the maritime supply chain and their components including petrochemical plants, tank infrastructures, port infrastructures and fleets. The complexity of the models grows considering the commercial constraints, added to the technical one mentioned above; in fact different type of contracts and very dynamic market evolution requires to develop a simulator able to support decisions leading to optimal, but robust solutions.

The authors propose to approach the simulation of the maritime logistics processes based on object oriented design and analysis (OODA) by identifying and defining each single element as an object characterized by its attributes and methods.

The authors referred to discrete event stochastic simulation paradigms to develop the related models. The result is an innovative simulation system defined MARLON (Maritime Logistics Network), that allows to model all the entities and processes related to the marine logistics; MARLON could be customized for different goods, in this paper it is proposed the application to liquid bulks for petrochemical industries; obviously the simulator allows to estimate costs and savings both in term of value and risk; in fact this simulator benefits of previous researches carried out by the authors (i.e. Charme Sequencer 2.0, MALOSI Simulator) focusing just on specific aspects of maritime logistics and chemical productions (Bruzzone, Serindat, Bertoni 2002).

In order to identify critical aspect that affect marine logistics, the authors propose the application of analysis techniques such as DOE (Design of Experiments) methodology and sensitivity analysis.

In addition the author are still integrating the current functionality of the model with advanced optimization solutions in order to investigate new improved intelligent optimization approaches in this field.

MARLON is a simulator able to demonstrate the enhanced advantages provided by using simulation in this framework; in fact by using MARLON it becomes possible to analyze complex scenarios and support the company decision making process with quantitative results and detailed risk analysis.

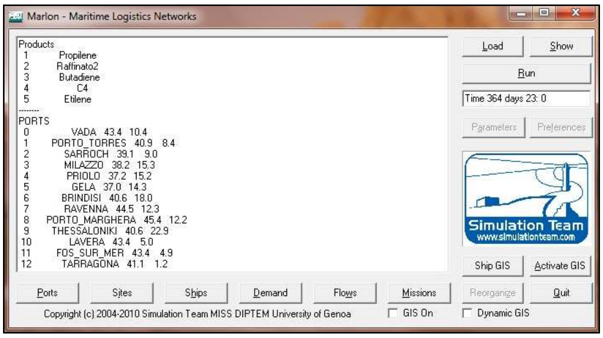


Figure 2. Marlon Simulator

The MARLON conceptual models were implemented in a discrete event stochastic simulator integrated with Google Earth APIs (MARLON).

In fact a basic use of these simulation models is related to fleet management; graphic interface is useful to navigate over the different lines and facilities and to quickly understand the implications of different solutions.

In addition to fleet management a great benefit of MARLON is the possibility to support a complex optimization process in bulk liquids marine logistics considering both costs and performances; the process is to proceed in the definition of the logistics by optimizing first of all the clustering of the chemical flows to be manage, then to identify optimal solutions in term of missions and related ports sequence; at this point it becomes possible to optimize tactical missions in term of fleet characteristics and contracts (Bruzzone et al. 2002)..

All these processes should be carried out interacting dynamically with the MARLON simulator by an automatic smart optimizer and/or by the decision makers.

The authors suggest to proceed by a combined approach that mix automatic optimization based on an intelligent solution dynamically connected with the simulator and expert test on the simulator; this approach allows to reuse logistics solutions proposed directly by the decision makers and to refine them progressively.

Figure 3. MARLON Ports GUI

The following objects are includes in MARLON simulator:

- *Ports* characterized by:
  - ID
  - Port Name
  - Coordinates
  - Input and Output Times
  - Docks Pumps Flows
  - Number of Docks
  - Docks Status
  - Prices for Ship Characteristics

- *Links* characterized by:
  - ID
  - Departure Port
  - Arrival Port
  - Distance
  - Reference Speed
  - Time (Average and Standard Devition)
  - Extra Cost (i.e. passage in a Canal)
  - Path Element

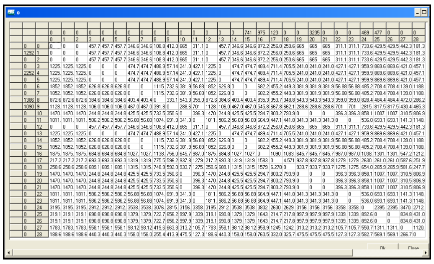
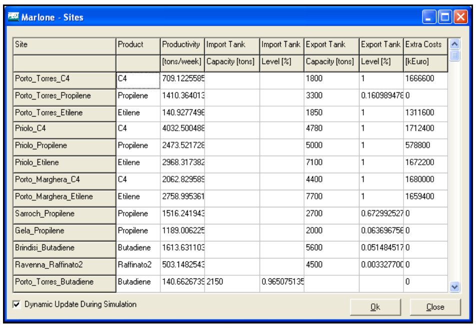


Figure 4. MARLON Links GUI

- *Missions* characterized by:
  - ID Mission
  - Flows
  - Sites Sequence
  - Ships allocated
- *Paths* characterized by:
  - ID
  - Path Element Name
  - Coordinates
- *Sites* characterized by:
  - ID
  - Port-Product
  - ID Port
  - Stop Cost
  - Shortage Cost
  - Minimum Weekly Production
  - Maximum Capacity
  - Product Types
  - Import / Export Products
  - Import / Export Tanks
  - Weekly Production Slots
  - Weekly Production Volumes (in term of statistical distributions)



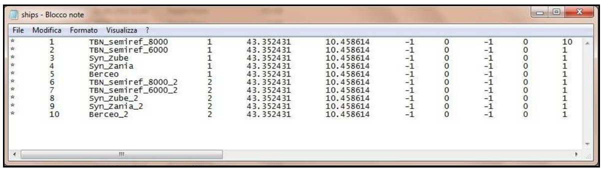
Marlone - Sites

Site	Product	Productivity [tons/week]	Import Tank Capacity [tons]	Import Tank Level [%]	Export Tank Capacity [tons]	Export Tank Level [%]	Extra Costs [kEuro]
Porto_Torres_C4	C4	709.1225585			1800	1	1666600
Porto_Torres_Propilene	Propilene	1410.364013			3300	0.160989478	0
Porto_Torres_Etilene	Etilene	140.9277496			1850	1	1311600
Priolo_C4	C4	4032.500488			4780	1	1712400
Priolo_Propilene	Propilene	2473.521728			5000	1	578800
Priolo_Etilene	Etilene	2968.317382			7100	1	1672200
Porto_Marghera_C4	C4	2062.829589			4400	1	1680000
Porto_Marghera_Etilene	Etilene	2758.995361			7700	1	1659400
Sarroch_Propilene	Propilene	1516.241943			2700	0.672992527	0
Gela_Propilene	Propilene	1189.006225			2000	0.063696756	0
Brindisi_Butadiene	Butadiene	1613.631103			5600	0.051484517	0
Ravenna_Raffinato2	Raffinato2	503.1482543			4500	0.003327700	0
Porto_Torres_Butadiene	Butadiene	140.6626739	2150	0.965075135			0

Dynamic Update During Simulation   Ok   Close

Figure 5. MARLON Sites GUI

- *Ship* characterized by the following attributes:
  - ID
  - Name
  - Type
  - Geographical Coordinates
  - Operational Status
  - Operational Time
  - Fuel Navigation Cost (for unit of distance/time)
  - Fuel Port Cost (for unit of time)
  - Ship Daily Cost
  - Navigation Speed
  - Draft
  - Number of holds
  - Capacity e Characteristics of each hold
  - Loads Carried
  - Data of Current Mission
  - Ports and Docks Sequence
  - On Board Pumps Flow



ships - Blocco note

File Modifica Formato Visualizza ?

*	1	TBN_semiref_8000	1	43.352431	10.458614	-1	0	-1	0	10
*	2	TBN_semiref_6000	1	43.352431	10.458614	-1	0	-1	0	1
*	3	Syn_Zube	1	43.352431	10.458614	-1	0	-1	0	1
*	4	Syn_Zania	1	43.352431	10.458614	-1	0	-1	0	1
*	5	Berceo	1	43.352431	10.458614	-1	0	-1	0	1
*	6	TBN_semiref_8000_2	2	43.352431	10.458614	-1	0	-1	0	1
*	7	TBN_semiref_6000_2	2	43.352431	10.458614	-1	0	-1	0	1
*	8	Syn_Zube_2	2	43.352431	10.458614	-1	0	-1	0	1
*	9	Syn_Zania_2	2	43.352431	10.458614	-1	0	-1	0	1
*	10	Berceo_2	2	43.352431	10.458614	-1	0	-1	0	1

Figure 6. Ship Object

Figure 7. MARLON Paths

- *Tank* characterized by:
  - ID
  - Port-Product
  - ID Product and Characteristics
  - Capacity, Minimum and Maximum Levels
  - Conversion Time and Costs
  - Current Level

- *Products* characterized by:
  - ID Product
  - Product Name
  - Characteristics
  - Compatibility Constraints

- *Flows* characterized by:
  - ID Flow
  - Flow Name
  - ID Product
  - ID Departure Port
  - ID Arrival Port
  - Quantity (t/week)

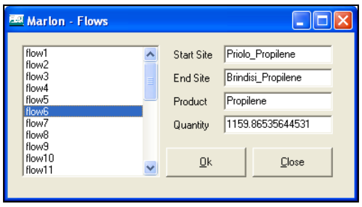


Figure 3. MARLON Flows GUI

Processing all the information resumed above MARLON Simulator identify the best fleet configuration by an heuristic computation procedure; the results obtained are synthesized and presented to the users through reports and animations, while details of each solution are available on demand.
This simulation model is able to simulate the following phenomena:

- Ship Fee Variation
- Product Market Prices Changes
- Production Cost behaviour
- Chemical Facility behaviour
- Navigation Time (including delays and time advances)
- Nautical Operations Time and Port Operations
- Tactical Missions Management by considering n Ports and m flows
- Level of Saturation of Vectors
- Evaluation of different sequencing alternatives
- Evaluation of different grouping alternatives
- Evaluation of Tactical Mission Costs
- Import/Export Operations related to the load type and to volumes
- Waiting time in Rada and Port Costs Evaluation including Controstallie
- Ships missions cycles

The geographic network is defined by links, therefore links in two directions can be different in term of distance and costs (i.e. channel fees); the user is entitled to define probability distributions for the different phenomena (i.e. Beta distribution or Gaussian distribution)
MARLON variables and parameters are easy accessible by users for changes the characteristic of the simulated scenario.
The update the MARLON DBASE is provided with a user-friendly GUI (Graphical Users Interface), by clicking on the apposite buttons it is possible to access input files or output report.
Several additional functions are allowed for flows management:

- *Load* for Input Files Data load and refresh
- *Show* for updating text and graphical areas
- *Run* to start up simulation

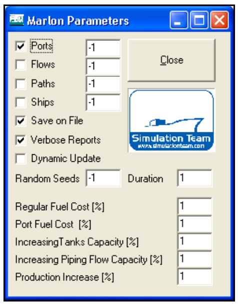


Figure 4. MARLON Parameters

For an high-end user is available also a parameters task button allows to manage simulation parameters such as:

- *Icons Types* to be visualized on Google Earth
- *Random seeds*
- *Duration*
- *Costs Coefficient* (i.e. port fuel cost)
- *Capacity Coefficient* of tanks or piping

The integration of MARLON with Google Earth APIs allows to activate GIS functions for the visualization of ships location and movements (determined by simulated coordinates) step by step:

- *Ship GIS* to visualize ships on Google map
- *Activate GIS* to activate GIS localization

Figure 5. View of some MARLON Ports

The results of the simulation runs are available for being analyzed by users in different ways: quick monitoring of flows, products, costs, profits and times during the simulation as well as by most accurate post processing analysis of the simulation output including cost trends evaluation for each site (i.e. including extra costs due to overstock and stock-out) and for each ship (i.e. fuel costs for navigation and port operations).

The major benefits related to the use of MARLON simulator are:

- Support the Optimization of the fleet configuration and port sequences during a ship mission made by the decision makers
- Support distributed decision making sharing information over the web among people located in different geographic areas; this allows to organise meetings and training sessions to evaluate different scenarios and solutions
- Improve the cooperation among different divisions of the same company, for example to put in contact logistics with commercial units or production sites generating a collaborative working environment with the benefit of a common simulation based framework for integrated quantitative analysis

Interoperability and integration with other modules is one of the innovative features of the DSS based on simulator (Bruzzone 2007). This feature is so useful, for instance, during meetings for tactical and strategic decisions on logistics and production (investments and budget) or videoconference to evaluate scheduling decision and critical operations. The experimentation was carried out using smart interactive whiteboards and dynamicallyb integration of MARLON with interactive GIS such as Google Earth.

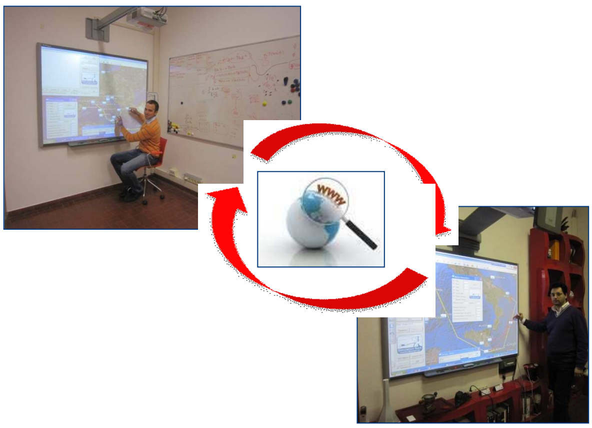


Figure 6. MARLON for "information logistics" during a distributed meeting over the web

The integration of MARLON with two modules: an optimizer and a sequencer allow to make more complete analysis and to propose new optimal solution or to refine existing ones. The best port sequence in a marine mission involving multiple picks and drops should be identify by an optimisation module due to the high number of variable; some previous research allowed to refine these algorithms and a demonstrator was developed by the authors for supporting implementation in industrial DSS (Charme Sequencer 2.0), these missions, obviously must satisfy the following constraints: required flows, technical commercial and operative constraints and available fleet.

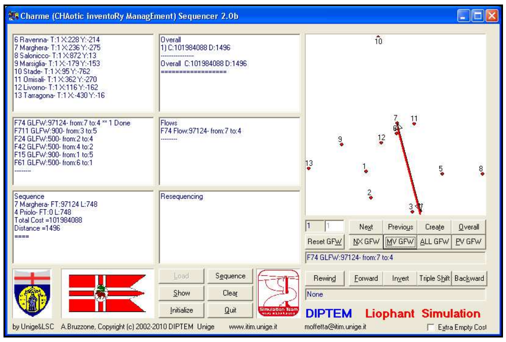


Figure 7. Charme Sequencer Module

This module allow to simulate:

- Ship's Saturation Levels
- Times and Costs for Port Operations
- Times and Costs of Navigation
- Times and Costs for Logistics Activities
- Ship fees

This additional module allow also the identification, definition and optimization of ship missions:

- Evaluation of different alternatives for Flows Grouping (Flows Clustering)
- Evaluation of different alternatives for Ports Sequencing (Ships Missions)
- Evaluation of cluster based Mission Costs

The second additional module is a sequencer that allows to optimise the vessels to be attributed to a mission from available fleet; the related algorithms was originally developed MALOSI models (Ship & Tank) to support industrial DSS in this area; these algorithms allows to identify risk and opportunities as well as optimal solutions in term of Ships management and Tank Infrastructures over stochastic complex scenarios. The outputs of MALOSI Ship 2.0 models includes the Optimal Ship Configuration able to satisfy the required flow of materials for a Mission
In similar way the outputs of MALOSI Tank 2.0 includes the best Import and Export Tank Infrastructures for a cluster of chemical plants/ports

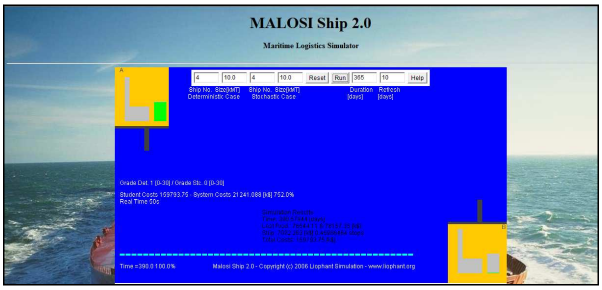


Figure 8. MALOSI Module

By using MSpE (Mean Square pure Error) and ANOVA (Analysis of Variance) techniques the authors successfully complete the MARLON VV&T (validation, verification and test) phase.
The next paragraph shows the obtained results over a case study extracted by a real industrial problem with some alternation on the original data due to their confidential nature.

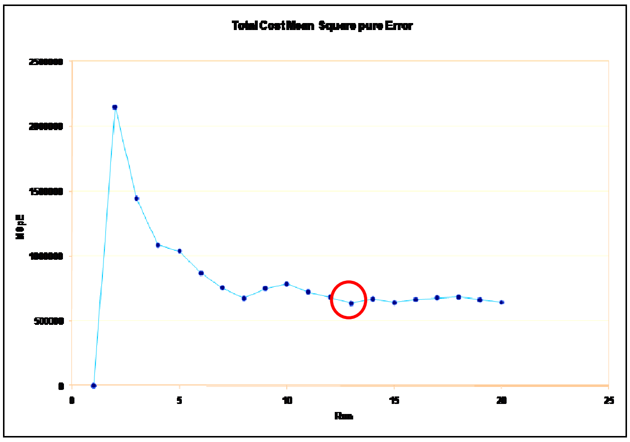


Figure 9. MSpE referred to Simulations runs

EXPERIMENTATION EXAMPLE

As mentioned before the scenario reproduced was very complex, stochastic factors and the non-linearity of the system need to be studied with care.
In order to analyze the stochastic influence on processes and to identify critical and significant parameters in terms of influence on the target functions (i.e. fleet total costs) the authors defined a detailed and careful experimental analysis.
Using Mean Square Pure Error methodology (MSpE) the authors performed statistical analysis in order to evaluate the experimental error and to measure the influence of stochastic variables onto the output target functions.
The use of that particular methodology allows to identify the correct simulation duration and, through the calculation of the confidence band, to know the fidelity of simulation output.

In this paper it is proposed the target function related to Ship Total Costs corresponding to fleet management costs; this KPI (Key Performance Index) includes the following eleemnts:

- Navigation Cost for each distance/time unit
- Operational Costs for each time unit
- Port Operations Class Cost
- Load Unit Cost
- Ship Mission Cost for each route and contract
- Lay-days, demurrage, etc.
- Penalties

In Figure 14 the MSpE analysis is proposed as well as the evolution of the Experimental Error referred to the simulation runs, as enhanced in that picture the stability of the Error is reached after 13 runs that represent the optimal number of replications over the same logistics solutions to properly take care of the influence of stochastic factors; this measure allows to estimate the tolerance of simulation results over the different target functions. The MSpE analysis is repeated for the following target function:

- Ships Total Costs
- Fuel Total Cost
- Ports Total Cost

in order to analyze the Experimental Error evolution respect the simulation time for identify the minimum simulation duration that allows to obtain reliable results.

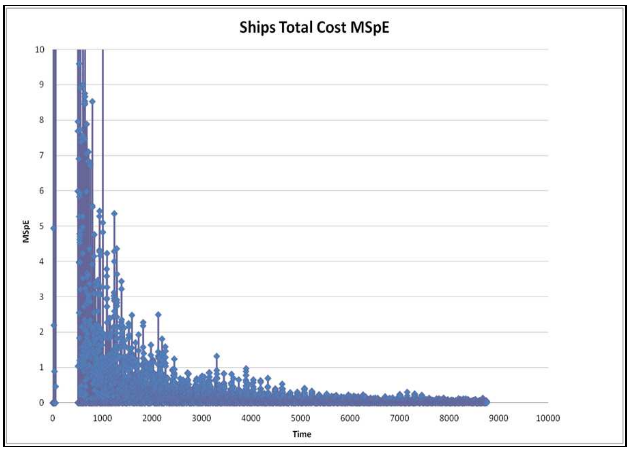


Figure 10. Ship Total Cost MSpE

Melting the results obtained, in terms of optimal run for each target function, is possible to determine the Correct Minimal Run Time by appliying the following relation:

CMRT = max(RTstc; RTftc; RTptc)

where:

RTstc = Run Time Ship Total Cost
RTftc = Run Time Fuel Total Cost
RTptc = Run Time Port Total Cost

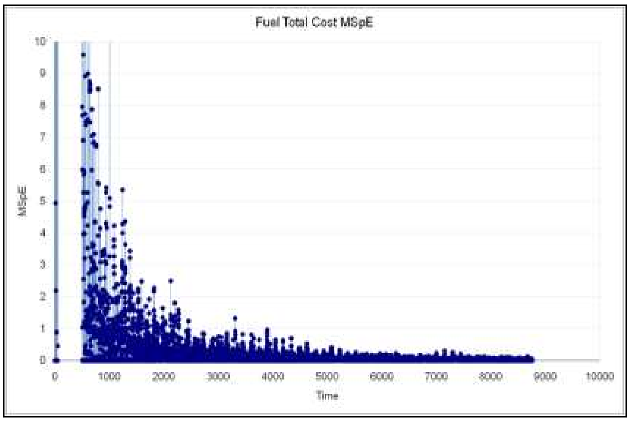


Figure 11. Fuel Total Cost MSpE

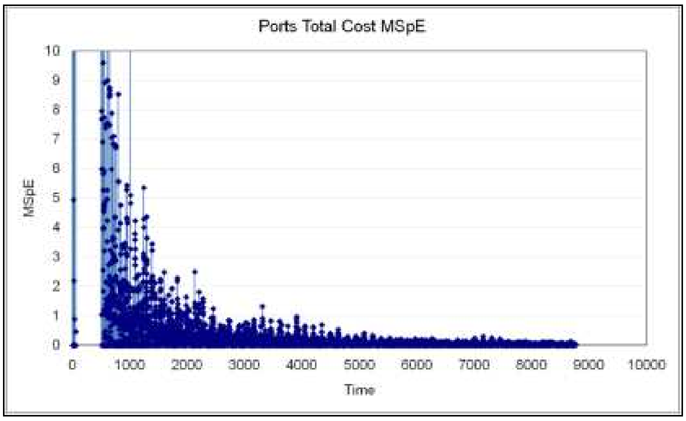


Figure 12. Ports Total Cost MSpE

The whole simulator is quite stable. As a matter of fact, it has been tested and validated and it reaches stability just after 20 simulated days (CMRT); so it means that MALOSI over the specific scenario under analysis it is able to support decision dealing within expected results over three weeks with very high degree of precision.
In order to analyze the impact of the input factors (and their interactions) on target functions the authors applied the sensitivity analysis techniques.

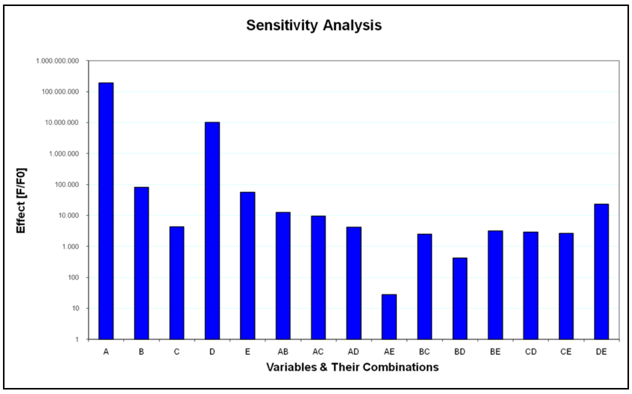


Figure 13. Sensitivity Analysis Results

In particular it is applied a Central Composite Design in order to complete this analysis reducing the efforts to estimate the stochastic factor influence; results are reported in the diagram below:
The graph shows the impact of the following input variable on the "Ship Total Cost" target function:
a) Production
b) Cost of Regular Fuel
c) Capacity of Tank
d) Cost of Port Fuel
e) Flow Capacity of Piping

The results are obviously strictly related to the variable ranges chosen and to the scenario used; in fact due to the non-linear nature of the problem the sensitivity could result very different changing this aspect; for instance in the proposed case the fleet is fixed and the range of variability of costs are estimated based on experts evaluation; despite very synthetic result proposed, it is interesting to note that this analysis allows not only to estimate the influence of the main input but even their interactions that obviously resulted by high due to the high level of complexity of this problem.

CONCLUSIONS

This research highlights the benefit of using simulation models to support analysis and decision making in complex logistics systems.
Focusing the study on maritime logistic fields the authors developed a simulator, MARLON, as support for marine supply chain management; the simulator is able to deal with fleet management and optimization and with evaluation of infrastructures and management policies over different scenarios. MARLON include innovative features such as interoperability with other modules; for instance MARLON is integrated through dynamic connection with the other modules (CHARME and MALOSI) for supporting optimization; another interesting features investigated in this research is the use of MARLON as distributed DSS for distributed teams working over the web; from this point of view the use of interactive smartboard and the integration with GIS (Google Earth) provide good results during the experimentation. At this stage MARLON is effectively implemented and the preliminary tests on real cases result very promizing. The experimental analysis confirms that the model is stable and reliable, and propose a methodology to effectively use as integrated systems for supporting decision makers in defining and managing marine logistics and fleet configuration within petrochemical industries.

REFERENCES

- Ayers J.B. (2001) "Handbook of Supply Chain Management", CRC Press Boca Raton, USA
- Baldwin C.Y. et al. (1993) "Managing the Value Chain", Harvard Business Review, Boston, MA
- Bolstorff P.,Rosenbaum R. (2003) "Supply Chain Excellence", Amacom, NYC
- Bronson R., Naadimuthu G. (1997) "Operations Research", McGraw Hill, NYC
- Bruzzone A.G. (2007) "Simulation Interoperability for Net-Centric Supply Chain Management", Invited Speech at Leading Edge in Supply Chain, Assologistica C&F, Confindustria Rome, July
- Bruzzone A.G., Bocca E. (2006) "Vessel Management Simulation", Proceedings of HMS2006, Barcelona, October
- Bruzzone A.G. (2004) "Introduction to Modeling and Simulation Methodologies for Logistics and Manufacturing Optimization", Vol 80, No.3 pg 119-120 ISSN 0037-5497
- Bruzzone A.G., Bocca E., Simeoni S. et al. (2004) "Advanced Systems for Logistics Network Design based on Interdisciplinary Approaches", Proceedings of I3M2004, Bergeggi Italy, October
- Bruzzone A.G., Cunha G.G., Landau L., Merkuryev Y. (2004) "Harbour and Maritime Simulation", LAMCE Press, Rio de Janeriro, ISBN 85-89459-04-7 (230 pp)
- Bruzzone A.G., Williams E.,(2004) "Modeling and Simulation Methodologies for Logistics and Manufacturing Optimization", Vol 80, No.3 pg 119-174 ISSN 0037-5497
- Bruzzone A.G., Serindat O., Bertoni F. (2002) "CHARME: CHAotic InventoRy ManagEment", Tech.Report of ICAMES, ENSO, Bogazici University, Istanbul, May
- Bruzzone A.G., R. Mosca, R. Revetria, A. Orsoni (2002) "System Architecture for Integrated Fleet Management: Advanced Decision Support in the Logistics of Diversified and Geographically Distributed Chemical Processing", Proceedings of AIS Simulation and Planning in High Autonomy Systems Conference, Lisbon, Portugal, April 7-10 pp. 309-314
- Chopra, S., Meindl, P., (2001), "Supply Chain Management", Prentice Hall, Upper Saddle River, New Jersey
- Bruzzone A.G., Giribone P., Carbone A. (1999) "Terminal Simulation as Support for Port Logistics", Proceedings of HMS99, Genoa, September 16-18
- Christopher, M., (1998) "Logistics and SCM", Prentice and Hall, London
- Clemen R.T, Reilly T. (2001) "Making Hard Decisions", Duxbury, Pacific Grove CA
- Giribone P., Bruzzone A.G. Carbone A. (1998) "Harbour Services and Lay-out Re-engineering by using Simulation", Proc.of 1st Workshop on Modelling & Simulation within a Maritime Environment, Riga, Latvia, September
- Hill David (1996) "Object-Oriented Simulation", Addison Wesley, Reading MA
- Lambert D, Stock J., "Strategic Logistics Management", McGraw-Hill, 2001
- Longo F., Mirabelli G., (2009) A state of the art on discrete event simulation and an application to supply chain inventory management. in: Proceedings of the International Conference on Harbour, Maritime & Multimodal Logistics Modeling and Simulation. Puerto de La Cruz, Tenerife, Spain, 23-25 September 2009, Puerto del la Cruz: A. Bruzzone, G. Cunha, R. Martinez,Y. Merkuriev, vol. I, p. 156-162Massei M. (2008) "Advanced Supply chain Protection & Integrated Decision support System", Invited Proceedings of AMS2008 Kuala Lumpur 13 – 15 May
- Merkuryev Y., Bruzzone A.G., Merkuryeva G., Novitsky L., Williams E. (2003) "Harbour Maritime and Multimodal Logistics Modelling & Simulation 2003", DIPTEM Press, Riga, ISBN 9984-32-547-4 (400pp)
- Monks J., (1996) "Operation Management", McGraw Hill, NYC
- Montgomery D.C. (2000) "Design and Analysis of Experiments", John Wiley & Sons, New York
- Mosca R, Giribone P., Bruzzone A.G. (1996) "Study of Maritime Traffic Modelled with Object-Oriented Simulation Languages", Proc. of WMC'96, San Diego, January 14-17
- Pareschi A., Persona A., Ferrari E., Regattieri A. (2002) "Logistica Integrata e Flessibile", Esculapio, Leonardo
- Pinedo M., Xiuli C. (1999) "Operations Scheduling with Applications in Manufacturing and Services", McGraw Hill, NYC
- Poirier C.C., Bauer M.J. (2001) "E-Supply Chain", Berret Koehler, SF
- Shapiro J.F. (2001) "Modeling the Supply Chain", Buxbury, Pacific Grove, CA
- Signorile R., Bruzzone A.G. (2003) "Harbour Management using Simulation and Genetic Algorithms", Porth Technology International, Vol.19, Summer2003, pp163-164, ISSN 1358 1759
- Stern C.W., Stalk G. (1998) "Perspective on Strategy", John Wiley & Sons, Hoboken, NJ
- Tremori A, Pierfederici L. (2007) "Simulation as Decision Support System for Quick Response Supply Chain", Proceedings of MAS2007, Bergeggi, October