SIMULATION BASED ANALYSIS OF A MANUFACTURING SYSTEM DEVOTED TO PRODUCE HAZELNUT BASED PRODUCTS

Agostino G. Bruzzone[(a)], Francesco Longo[(b)]

[(b)] DIME - University of Genoa, via Opera Pia 15 - 16145 Genova, Italy
[(b)] MSC – LES, Mechanical Department, University of Calabria, Via Pietro Bucci, Rende, 87036, ITALY

[(a)] agostino@itim.unige.it, [(b)]f.longo@unical.it

ABSTRACT

The main goal of this paper is to propose a simulation model that can be used as decision support tool within a manufacturing system devoted to produce hazelnuts based products. The simulation model is capable of investigating different manufacturing systems configurations by considering user-defined input parameters and multiple performance measures. The paper briefly describes the simulation model and proposes an application example to provide evidence on the relevance of the proposed simulation model.

Keywords: Industrial Plants, Modeling & Simulation, Performance Analysis

1. INTRODUCTION

Considering the actual financial crisis (still ongoing in many European countries) manufacturing systems must be able to react at different levels (strategic, tactic and operative) to unexpected changes (both in terms of opportunities and problems). Strategic decisions in manufacturing systems typically concern design problems and resources allocation in the medium/long period (i.e. a new plant lay-out, products assortment, new production machines, etc.). Tactical decisions are related to the planning and control of the manufacturing system resources (manufacturing policies, warehouse and logistics policies, customers' services, etc). Finally, operative decisions are mainly related to the manufacturing system management in the short period (i.e. shop orders scheduling, resources and materials availability, etc.). Usually problems at any of these levels may involve contrasting objectives therefore requiring a strong experience (for people involved in the decision process) as well as advanced decision support tools.

In this context Modeling & Simulation (M&S) is widely used in manufacturing systems design and management to define system requirements, to explain system behavior, to diagnose problems, to take into account the effects of specific constraints, to test different production policies, to investigate different operative scenarios, to evaluate the impact of different human factors on industrial and business processes (Bruzzone, 2002; Bruzzone, 2004, Bruzzone et al., 2007). In fact a survey of the current state of the art clearly reveals that a tremendous amount of research works have been published (over the last 50 years) in this area (Callahan *et al.* 2006).

Generally speaking, a M&S based approach generally does not provide exact or optimal solutions to problems but it allows users analyzing the behavior of complex systems, performing what-if analysis and choosing correctly among different possible scenarios (Karacal 1998; Banks 1998). In fact, oppositely to analytical approaches, the main advantage of M&S when studying and analyzing manufacturing and logistic systems is the possibility to take into consideration multiple aspects without introducing restrictive assumptions. M&S offers the possibility to generate reliable output results, to describe and analyze the behavior of existing systems while changing initial conditions and operative scenarios.

According to Smith (2003), simulation based approaches can be used both for existing (see for instance Bruzzone et al., 1999) and for new manufacturing systems (still not in existence, Longo and Mirabelli, 2009). Examples of research works in which M&S has been used to support manufacturing systems design and/or management can be found in Berry (1972), Nunnikhoven and Emmons (1977), Stenger (1996), Mullarkey *et al.* (2000), Longo *et al.* (2005), Longo et al. (2012), Ren et al (2012). M&S is also often used in combination with artificial intelligence techniques (above all for solving multi-objective optimization problems). Classifications frameworks for simulation based optimization can be found in Andradottir (2005), Fulcher (2008); examples of applications can be found in Mosca et al. (1997), Giribone and Bruzzone, (1999).

The focus of this paper is a manufacturing system devoted to produce hazelnuts based products. The authors use a M&S based approach to develop a decision making tool that can be used by production managers for investigating different manufacturing system configurations under the effect of multiple critical parameters and by monitoring multiple performance measures. Therefore the goal of this paper is not to find out the best configuration of the manufacturing system but to show the potentials of the simulation approach in the decision making process and how an ad-hoc developed simulation model can be an

advance tool to support decision taken at any level by the company production managers.
The paper is organized as follows: Section 2 reports a description of the hazelnuts market; section 3 presents the hazelnuts production process while section 4 briefly describes the main simulation model features. Section 5 proposes the application examples and the experimental analysis to show the relevance of the proposed approach. Finally, conclusions summarise the main results of the study.

2. THE HAZELNUTS MARKET

According to the Food and Agriculture Organization of the United Nations (FAO), the hazelnuts truck farming covers around 847,435 hectares with an estimated production of 1,052,000 tons per year. Turkey is the major hazelnuts producer (75% of the total hazelnuts production) followed by Italy (11%), USA (3%), Azerbaijan (3%) and Spain (2%).
Therefore hazelnuts' price strongly depends on the international trades and transactions, with Turkey playing the most important role in determining the hazelnuts price. The most important influence on the price is the amount of production placed in international markets from Turkey, which alone represents 70% of the world. However, Turkey usually enters controlled quantities of hazelnuts in the market to keep under control the prices (in order to avoid drastic reduction of international prices with negative consequences on income levels of its farmers).

Even with a strong difference compared to Turkey in terms of total production per year, Italy has a long tradition and experience in the hazelnuts production and today faces the national and international market with a considerable hazelnuts based products assortment. In fact, during the last years, hazelnuts production has received funding and incentives (at both European and national level) for the introduction of innovations for increasing quality standards (i.e. new methods of cultivation have been introduced to optimize harvesting techniques, times and to ensure environment protection). The scenario that characterizes the Italian hazelnuts sector is rather complex: the land dedicated to hazelnuts truck farming is continuously increased during the last 50 years (+126%) as well as the total production passed from about 24,000 tons/year up to 105,000 tons/year. In Italy, most of the land area used for hazelnuts truck farming is located in the South. The first stage is represented by agricultural producers that sell their products to both national and international buyers (mainly represented by the confectionery industry). Hand harvesting affects for about one third the cost of the total crop (in case of mechanized harvesting such percentage drops to 19%). Usually mechanical harvesting can be facilitated by chemical treatments, to promote the maturation and the simultaneous fall of hazelnuts.

Production facilities require complex industrial/manufacturing systems characterized by different types of operations including sizing, shelling, roasting, grain, packaging and storage. The technical characteristics of the manufacturing system devoted to produce hazelnuts based products considered in this paper are briefly presented in the next section.

Specifically, with regard to Calabrian territory (South Part of Italy) the initiative to design an integrated manufacturing system for processing semi-finished hazelnuts has been undertaken in order to meet the demand of “Pizzo Homemade” ice cream.

3. THE HAZELNUTS PRODUCTION PROCESS

The production process of the manufacturing system considered in this paper consists of several stages. The first phase consists of cleaning and drying operations. Raw hazelnuts are cleaned in two ways: with air jet (to remove impurities) and with water to separate the heavier ones. In particular the raw hazelnuts are placed in a bulk hopper that moves (by gravity) the hazelnuts on a bucket elevator that, in turn, transports them up to the entrance of the impurities separator. Inside the separator hazelnuts are invested by a strong jet of air which ensures the separation of the raw hazelnuts from light impurities such as leaves, twigs, shells, etc. Then the product is conveyed inside a destoner that is used for the elimination of heavier impurities (i.e. stones). In particular, hazelnuts are moved to the subsequent operation by a flow generated by an external unit, while the heavier elements are dragged downwards from the outflow. Another bucket elevator transports the cleaned hazelnuts till the entrance of the dryer.
Within the drying chamber hazelnuts are subject to a jet of hot air (45°C - 60°C) to reduce the moisture (this phase is also useful to guarantee the preservation of the hazelnuts quality over the time) and to prepare hazelnuts to the successive operations. This operation also guarantees bacteria destruction and weakening of the shell. After this phase some of these hazelnuts are directly packed (hazelnuts in shell) while the remaining hazelnuts continue the production process through the pre-calibrating and shelling operations.

At this stage, the hazelnuts are placed again in a bulk hopper and then by gravity in a bucket elevator that moves them till the entrance of a roller sizer. This machine subdivides hazelnuts in different sizes, depending on the shells dimensions. Therefore the hazelnuts are conveyed to the Sheller that deprives hazelnuts for their shells; once deprived of their shells, hazelnuts are subject to further calibration (this time the hazelnuts must respect all the quality standards required in order to proceed with the subsequent operations). Finally, a spiral conveyor moves the hazelnuts to the subsequent phase.

The subsequent phase is the roasting operation; this operation is required to give hazelnuts a complete dehydration, oxidation and therefore more flavors. At the end of the roasting operation a cooling tunnel brings roasted hazelnuts at the environment temperature. The product, deprived of the outer shell, is then moved through a conveyor belt where operators manually remove the over-burned hazelnuts. At this time, some of the hazelnuts are packed (roasted hazelnuts) while the remaining hazelnuts continue the process through the graining and refining operations. Graining operations are devoted to produce chopped hazelnuts (that will be packaged in a granular form). First the hazelnuts go through the grinder machine, where they are crushed and reduced to chopped hazelnuts. Now, the product, in granular form, passes through a circular vibrating screen that removes dust from chopped nuts. Finally a pneumatic separator separates the granules of different dimensions.

The last phase is the refining operation. The roasted nuts are placed in a flour mill that reduces them into flour. Then the flour is placed in steel tanks where it is mixed with water and sugar and then conveyed into the refiner, where it is continuously kneaded to form the hazelnuts paste. The paste is sieved in the vibrating filter to provide additional smoothness and eliminate possible solid components. At the end the hazelnuts paste is placed in a stainless steel tanks, waiting to be moved with a volumetric pump into stainless steel containers that are successively stored in refrigerators.

Figure 1 shows a schematization of the manufacturing process highlighting the different manufacturing system departments and the transport operations.

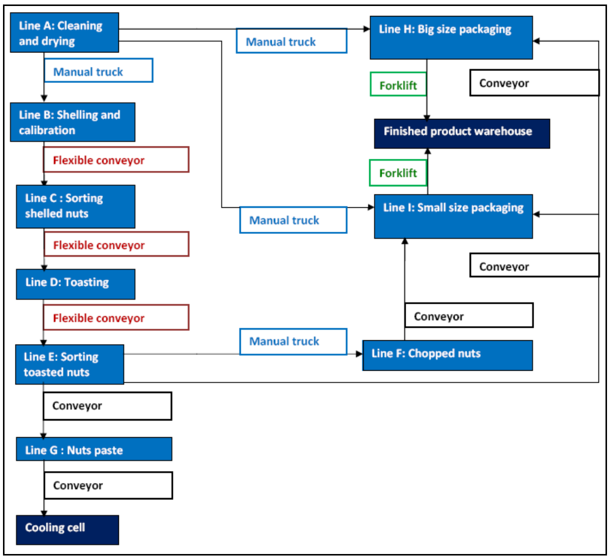

Figure 1: manufacturing process schematization

Information about the estimated production of the manufacturing system considered in this paper are reported in table 1 (expressed in tons per year for each type of product).

4. THE SIMULATION MODEL

Authors have a long experience in developing simulation models (also using adavanced approach based on 3D virtual simulation) for supporting the decision process both in the Industry and Logistics area.

Table 1: Estimated production of the manufacturing systems

Product type	Quantity (tons per year)
Hazelnuts in Shell	60
Roasted Hazelnuts	30
Chopped Hazelnuts	60
Hazelnut Paste	37

Example of research works developed by authors in this area can be found in Bruzzone and Longo, (2012), Longo et al. (2012), Bruzzone and Longo (2010), Longo (2010); Cimino et al. (2009); Curcio and Longo (2009), Longo and Mirabelli (2009), Longo and Mirabelli, 2008, De Sensi et al. (2008).

Based on the description reported in the previous section the authors have implemented a java-based simulation model able to recreate the entire hazelnuts production process. The simulation model includes the following elements:

- static entity: workers performing manual operations (i.e. manual sorting of over-burned hazelnuts) and manual transportations.
- dynamic entities: hazelnuts in all the states of transformation (freshly harvested, cleaned, dried, shelled, roasted, chopped nuts, hazelnuts flour, hazelnuts paste), containers used for transportation (canvas bags, stainless steel containers, etc.)
- resources: constituted by machines and conveyor belts that are located within the different manufacturing system departments
- queue: intermediate buffers in which work in process in accumulated

Figure 2 shows the animation the main frame of the manufacturing system simulation model. The mean utilization level of each machine is displayed by means of bar indicators positioned in correspondence of each machine as well as the work in process is displayed by using arc indicators positioned in correspondence of the intermediate buffers. In addition, the mean level of utilization of the intermediate buffers is displayed by using text messages.

The simulation model is equipped with a control panel that provides the user with the possibility to change the most important parameters governing the manufacturing system. In particular it is possible to change the production capacity of each machine, the source rate defined as the amount of raw hazelnuts entering the manufacturing system per unit of time, the number of workers, the products assortment and the amount of each product type to be produced.

The simulation model is also equipped with a section dedicated to display the simulation results. Multiple key performance indicators are displayed: among others, the flow time for each shop order, quantity of quantity of dried, roasted, grained hazelnuts

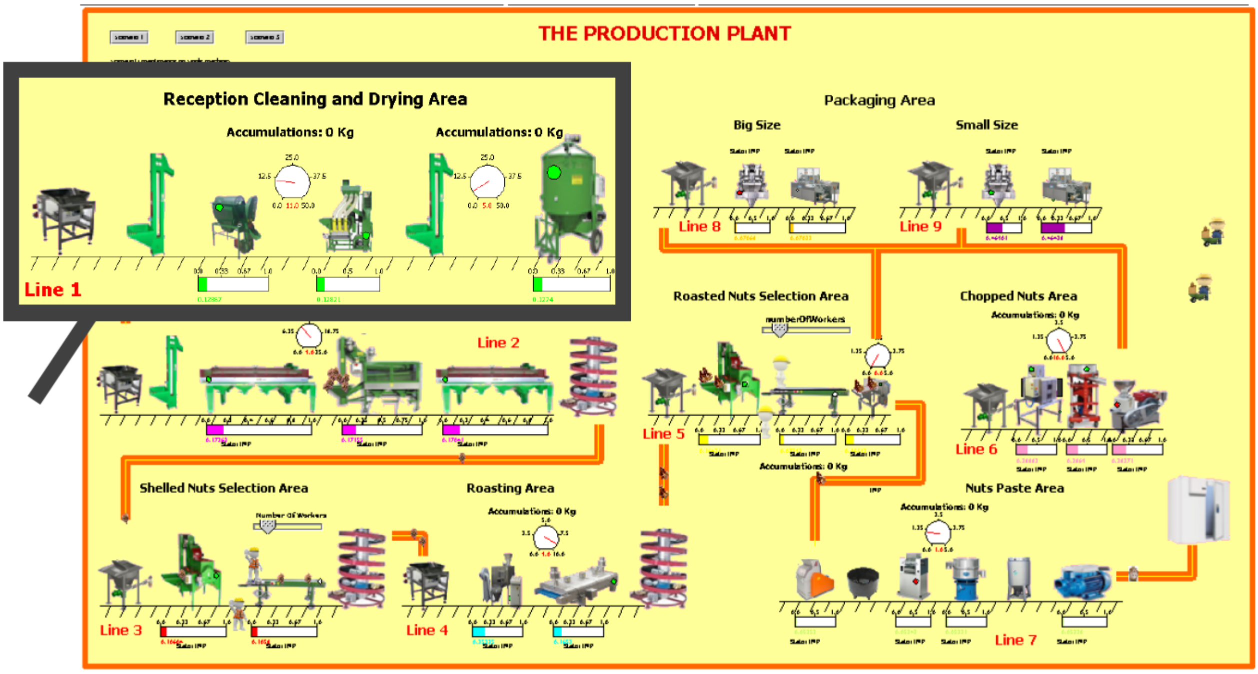

Figure 2: the manufacturing system simulation model

and hazelnuts paste, the number of packages for each product type, machines average utilization level and buffers saturation level.

5. EXPERIMENTAL ANALYSIS

The main idea behind the simulation model proposed in this paper is to provide the production managers operating in the manufacturing system with a decision making tool capable of analyzing different manufacturing system configurations by using an approach based on multiple performance measures and user-defined set of input parameters. Therefore the application example proposed in this section has been developed for understanding tool potentials from the production engineers' perspective.

It easy to understand that a production manager needs a decision making tools capable of investigating the effects of critical factors on multiple performance measures therefore a decision making tool should provide managers with high flexibility in terms of scenarios definition, critical parameters and performance measures selection.

In the application example proposed in this section the authors decide to use the simulation model to investigate the behavior of several performance indicators under different operative conditions. The simulation model capabilities as decision making tool are strongly amplified if Design of Experiment (DOE) and Analysis of Variance (ANOVA) are respectively used for experiments planning and simulation results analysis. Before carrying out the experimental analysis some preliminary simulations have been executed to test the capability of the simulation model to recreate the real manufacturing system.

The results of these preliminary analyses are reported in table 2 in terms of simulated annual production and real annual production

Table: Comparison between the simulated annual production and the real annual production

Annual Production [tons/year]			
Product Type	**Simulated**	**Real**	**Difference**
Hazelnuts in Shell	60,575	60.0	0.94%
Roasted Hazelnuts	29,580	30.0	1.41%
Chopped Hazelnuts	60,040	60.0	0.06%
Hazelnuts Paste	37,090	37.0	0.24%

The main factors considered as "critical parameters" that can impact the system performances are:

- *Source Rate*, SR, defined as the quantity of raw hazelnuts in input to the production process per unit of time
- *Production Mix*, PM, defined as the mix of products that are currently worked in the manufacturing system
- *Customer Rate*, CR, defined as the number of external customers per unit of time (the Customer Rate simulates the external demand intensity)
- *Working Shifts*, WS, defined as the number of working hours per day.

In this study, we have chosen, for each factor, different number of levels as reported in table 3.

Table 3: Factors and Levels

Factors	Level 1	Level 2
SR	90%	110%
PM	15 %	25%
CR	90%	110%
WS	80%	125%

The meaning of the factors levels can be explained as follows. The minimum level and the maximum level of the source rate are 90% and 110% of the actual value respectively; the actual value of the source rate is the one currently used in the real manufacturing system. The minimum and the maximum level of the production mix are 15% and 25%; the two levels are the percentages of the total raw hazelnuts in input to the manufacturing system that will be stored as hazelnuts in shell while the remaining part will be used for roasted hazelnuts, chopped hazelnuts and hazelnuts paste. The minimum level and the maximum level of the customer rate are 90% and 110% of the actual value respectively; the actual value of the customer rate is the average value of the customer rate in the real system. The minimum level and the maximum level of the working shift are 80% and 125% of the actual value respectively; the actual value of the working shift is the one currently used in the real system.

The following performance measures are monitored during each simulation run:

- Average Utilization Level of each Production line;
- Flow Time of small packages of hazelnuts in shell
- Flow Time of big packages of hazelnuts in shell
- Flow Time of small packages of roasted hazelnuts
- Flow Time of big packages of roasted hazelnuts
- Flow Time of chopped hazelnuts
- Flow Time of hazelnuts paste
- Quantity in output for each product type
- Work in Process
- Average Lead Time
- Percentage of Fulfilled Orders
- Total Back Orders
- Total Probability of Stockout
- On Hand Inventory for hazelnuts in shell
- On Hand Inventory for roasted hazelnuts
- On Hand Inventory for chopped hazelnuts
- On Hand Inventory for hazelnuts paste
- Total On Hand Inventory

Note that the production manager can easily define a different scenario by selecting different factors or different factors levels. To this end the manager can easily implement new factors/parameters thanks to simulator architecture completely based on java programming code. The objective of the application example is to understand the effects of factors levels on the performance measures reported above.

Checking all possible factors levels combinations (by using a factorial experimental design) requires 16 simulation runs; if each run is replicated 5 times we have 80 replications. To monitor the performances of the manufacturing system requires the collection of a huge number of simulation results. To this end the simulation model has been jointly used with Microsoft Excel and Minitab. At the end of each replication the simulation results are transferred in Excel spreadsheets. By means of routines programmed in Visual Basic the performance measures average values are calculated. Such values can be easily copied on a Minitab project (opportunely set with the same design of experiments) for statistic analysis. The Microsoft Excel interface has been implemented for correctly working in each scenario (not only in the application example proposed). The results in terms of mean values calculated by Microsoft Excel can be analyzed by using plots and charts (i.e. working in process versus source rate, probability of stock-out versus customer rate, etc.). Therefore the use of the simulation model does not necessarily require Design of Experiments or Analysis of Variance or any kind of statistical methodologies or software.

5.1. Simulation Results and discussion

Considering that currently there are 18 different performance measures implemented within simulation model , we cannot report in this paper all the simulation results of the application example; the following figures summarize some simulation results. The results of the factorial experimental design have been analyzed by using the ANOVA.

The ANOVA allows to evaluating those factors that have a real impact on the performance measures considered by decomposing the total variability of the performance measures into components; each component is a sum of squares associated with a specific source of variation (treatments) and it is usually called treatment sum of squares. Without enter in formulas details, if changing the levels of a factor has no effect on variance of the performance measure, then the expected value of the associated treatment sum of squares will be an unbiased estimator of the error variance (this is known as null hypothesis, H0). On the contrary, if changing the level of a factor has effect on the performance measure, then the expected value of the associated treatment sum of squares will be the estimation of the error plus a positive term that incorporates the variation due the effect of the factor (alternative hypothesis, H1). It follows that by comparing the treatment mean square and the error mean square we can understand which factors have effect on the performance measure (Longo and Mirabelli, 2008). Further information on ANOVA can be found in any statistics handbook (see for instance Montgomery and Runger (2006).

The figure 3 shows the main effects plots (obtained by plotting the meta-model obtained from the analysis of variance) for the average flow time of the chopped hazelnuts. It is possible to observe that both the Source Rate and the Production Mix have an impact on the average flow time. In particular, the average flow time increases roughly of 17% when the Source Rate changes its value from the 90% to 110%, demonstrating as an overuse of the manufacturing system can quickly bring to a rapid increase of the products flow times. Similar results have been obtained from the hazelnuts in shell, roasted hazelnuts and hazelnuts paste.

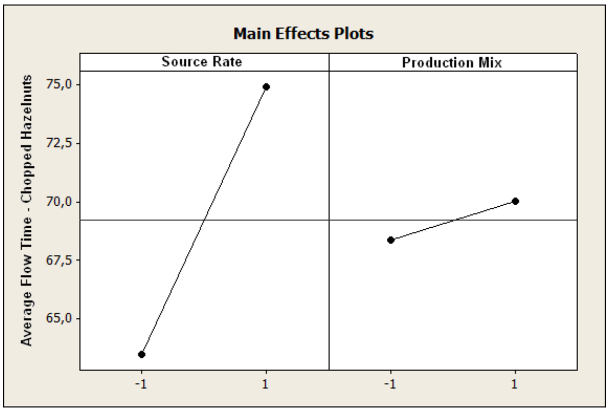

Figure 3: Average Flow time for Chopped Hazelnuts versus Source Rate and Production Mix

The figure 4 shows the main effects plot for the average percentage of fulfilled orders. It is possible to observe that the percentage of fulfilled orders increases up to 97% when the source rate is at its 110% value, while an increase of the customer rate brings to a reduction of the percentage of fulfilled orders (with an increase not shown of orders backordered). The effect of the production mix is smaller compared to the effects of both Source Rate and Customer Rate.

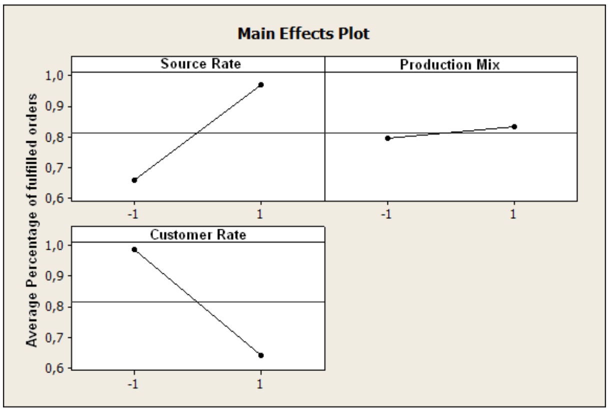

Figure 4: Average Percentage of fulfilled orders versus Source Rate, Production Mix and Customer Rate

Now let us also consider for this second case the interaction effects (shown in figure 5). There are remarkable interaction effects both between the Source Rate and the Production mix and the Source Rate and the Customer Rate. The percentage of fulfilled orders increases when both the Source Rate and the Production Mix are at their maximum value. In addition, the interaction between the Source Rate and the Customer Rate clearly shows that an increase of the Customer Rate when the Source Rate is at its lowest value may have a tremendous impact on the percentage of fulfilled orders.

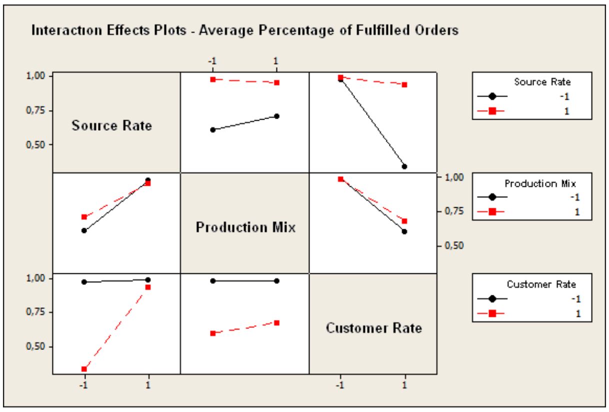

Figure 5: Interaction Effect Plots: Average Percentage of fulfilled orders versus Source Rate, Production Mix and Customer Rate

An additional cas, figure 6 shows how the simulation model can be used to evaluate the effect of Source Rate, Production Mix, Customer Rate and Working Shift on the total On Hand Inventory.

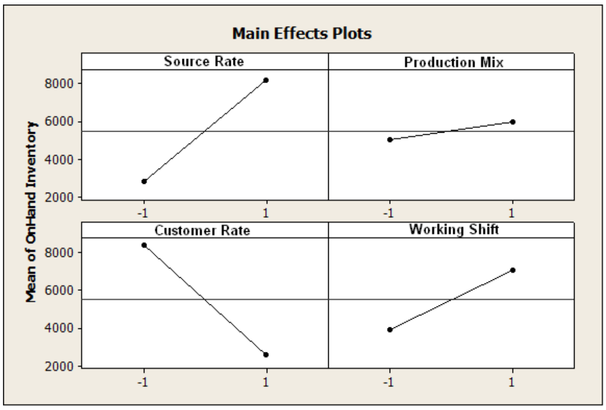

Figure 6: Average On Hand Inventory versus Source Rate, Production Mix, Customer Rate and Working Shift

Needless to say similar results have been obtained for all the other performance measures.

6. CONCLUSIONS

As already stated in the introduction, the aim of the paper is not to find out the best configuration of the manufacturing system but to show the potentials of the simulation model in the decision making process and how the simulation model proposed in this paper can be used by a production manager.

The high level of results detail (analysis of multiple performance measures in correspondence of multiple critical factors) helps in understanding the simulation model capabilities as decision making tool. In effect as reported in literature the decision making process within a manufacturing system requires accurate analysis of the current situation as well as of alternative scenarios. In addition the simulator architecture jointly with Excel and Minitab spreadsheets guarantees high flexibility in terms of scenarios definition, high efficiency in terms of time for executing simulation runs and analyzing simulation results.

REFERENCES

Balci, O., 1998. Verification, Validation and Testing. In: J. Banks, *Handbook of Simulation*, John Wiley & Sons, Inc., 335–393.

Banks, J., 1998. *Handbook of Simulation*. John Wiley & Sons, Inc.

Berry, W.L., 1972. Priority scheduling and inventory control in a job shop lot manufacturing systems. *AIIE Transactions*, 4, 267–276.

Bocca, E., Curcio, D., Longo, F., Tremori, A., 2008. Warehouse and internal logistics management based on modeling & simulation. *Proceedings of the International Workshop on Modeling & Applied Simulation 2008*, pp. 41–48. September 17–19, Campora S.Giovanni, Cosenza, Italy.

Bruzzone A.G., Giribone P, Vio F. (1999). Genetic Algorithms and Simulation for Supporting Layout Re-Engineering of Automotive Component Production Facilities. International Journal of Flexible Automation And Integrated Manufacturing, vol. 7, p. 379-391, ISSN: 1064-6345

Bruzzone A.G. (2002). Introduction to the Special Issue on Simulation in Supply Chain Management. SIMULATION, vol. 78, p. 284-286, ISSN: 0037-5497.

Bruzzone A. G. (2004). Preface to modeling and simulation methodologies for logistics and manufacturing optimization . Simulation, vol. 80, pp. 119-120, ISSN: 0037-5497, doi: 10.1177/0037549704045812

Bruzzone A.G., Briano A., Bocca E., Massei M. (2007). Evaluation of the impact of different human factor models on industrial and business processes". Simulation Modeling Practice and Theory, vol. 15, p. 199-218, ISSN: 1569-190X.

Bruzzone, A.G., Curcio, D., Mirabelli, G., Papoff, E., 2009. Warehouse management: inventory control policies comparison. *Proceedings of the International Workshop on Modeling & Applied Simulation 2009*, pp. 148–154. September 23–25, Puerto de La Cruz, Tenerife, Spain.

Bruzzone A.G., Longo F., (2012). 3D Simulation as Training Tool in Container Terminals: the TRAINPORTS Simulator. Journal of Manufacturing Systems, doi: 10.1016/j.jmsy.2012.07.016, ISSN: 0278-6125.

Bruzzone A.G, Longo F., 2010. An advanced System for supporting the decision process within large scale retail stores. SIMULATION, vol. 86, p. 742-762,, doi: 10.1177/0037549709348801.

Callahan, R.N., Hubbard, K.M., Bacoski, N.M., 2006. The use of simulation modelling and factorial analysis as a method for process flow improvement. *Advanced Manufacturing Technology*, 29, 202–208.

Castilla I., Longo F., 2010. Modelling and Simulation Methodologies, Techniques and Applications: a State of the Art Overview. International Journal of Simulation & Process Modelling, vol. 6(1); p. 1-6, ISSN: 1740-2123.

Cimino A., Longo F., Mirabelli G., 2009. A Multi-Measures Based Methodology for the Ergonomic Effective Design of Manufacturing System Workstations. INTERNATIONAL JOURNAL OF INDUSTRIAL ERGONOMICS, vol. 39; p. 447-455, ISSN: 0169-8141, doi: 10.1016/j.ergon.2008.12.004

Cimino, A., Curcio, D., Mirabelli, G., Papoff, E., 2008. Warehouse inventory management based on fill rate analysis. *Proceedings of the International Workshop on Modeling & Applied Simulation 2008*, pp. 23–30. September 17–19, Campora S.Giovanni, Cosenza, Italy.

Curcio D, Longo F., 2009. Inventory and Internal Logistics Management as Critical Factors Affecting the Supply Chain Performances. *International Journal of Simulation & Process Modelling*, vol. 5(4); p. 278-288, ISSN: 1740-2123

De Sensi G, Longo F, Mirabelli G (2008). Inventory policies analysis under demand patterns and lead times constraints in a real supply chain. International Journal of Production Research, vol. 46, p. 6997-7016, ISSN: 0020-7543, doi: 10.1080/00207540701528776

Dunn, R.H., 1987. The quest for software reliability. In: *Handbook of Software Quality Assurance*, Van Nostrand Reynold, 342–384.

Eben-Chaime, M., Pliskin, N., Sosna, D., 2004. An integrated architecture for simulation. *Computer and Industrial Engineering*, 46, 159–170.

Fox, D.G., 1981. Judging air quality model performance. *Bulletin of the American Meteorological Society*, 62, 599–609.

Giribone P., Bruzzone A.G. (1999). Artificial Neural Networks as Adaptive Support for the Thermal Control of Industrial Buildings. International Journal of Power & Energy Systems, vol. 19, No.1, p. 75-78, ISSN: 1078-3466.

Karacal, S.C., 1998. A novel approach to simulation modeling. *Computers & Industrial Engineering*, 34 (3), 573–587.

Loague, K., Green, R.E., 1991. Statistical and graphical methods for evaluating solute transport models: overview and application. *Contaminant Hydrology*, 7 (1-2), 51–73.

Longo F, Massei M, Nicoletti L (2012). An application of modeling and simulation to support industrial plants design. International Journal of Modeling, Simulation, and Scientific Computing, vol. 3, pp. 1240001-1-1240001-26, ISSN: 1793-9623, doi: 10.1142/S1793962312400016

Longo F (2010). Design and integration of the containers inspection activities in the container terminal operations. International Journal of Production Economics, vol. 125, p. 272-283, ISSN: 0925-5273, doi: 10.1016/j.ijpe.2010.01.026

Longo, F., Mirabelli, G., Papoff, E., 2005. Material flow analysis and plant lay-out optimization of a manufacturing system. *International Journal of Computing*, 1 (5), 107–116.

Longo F., Mirabelli G., 2009. Effective Design of an Assembly Line using Modeling & Simulation. *Journal of Simulation*, vol. 3; p. 50-60, ISSN: 1747-7778, doi: 10.1057/JOS.2008.18.

Longo F., Mirabelli G., 2008. An Advanced Supply Chain Management Tool Based on Modeling & Simulation. COMPUTERS & INDUSTRIAL ENGINEERING, vol. 54/3; p. 570-588, ISSN: 0360-8352, doi: 10.1016/j.cie.2007.09.008.

Montgomery D.C., Runger G.C., 2006. Applied Statistics and Probability for Engineers. John Wiley & Sons.

Mosca R., Giribone P., Bruzzone A.G., Orsoni A., Sadowski S. (1997). Evaluation and Analysis by Simulation of a Production Line Model Built with Back-Propagation Neural Networks. International Journal of Modelling & Simulation, vol. Vol.17, no.2, p. 72-77, ISSN: 0228-6203

Mullarkey, P., Gavirneni, S., Morrice, D.J., 2000. Dynamic output analysis for simulations of manufacturing environments. *Proceedings of the 2000 Winter Simulation Conference*, pp. 1290–1296. December 10–13, Orlando, Florida (USA).

Nunnikhoven, T.S., Emmons, H., 1977. Scheduling on parallel machines to minimize two criteria related to job tardiness. *AIIE Transactions*, 3, 288–296.

Ren, L., Zhang, L., Tao, F., Zhang, X., Luo, Y., Zhang, Y. (2012). A methodology towards virtualisation-based high performance simulation platform supporting multidisciplinary design of complex products. Enterprise Information Systems, Volume 6, Issue 3, pp. 267-290.

Smith J. S., Survey in the use of simulation for manifacturing system design and operation, J. Manuf. Syst. 22(2):157–171, 2003.

Stenger, A.J., 1996. Reducing inventories in a multi-echelon manufacturing firm: a case study. *Production Economics*, 45, 239–249.

Andradottir S., 2005. An overview of simulation optimization via random search, in Henderson S. G., Nelson B. L. (eds.), Handbooks in Operations Research and Management Science: Simulation, Chapter 21, Elsevier, 2005.

Fulcher J., 2008. Computational intelligence: An introduction, Studies in Computational Intelligence 115:3–78

AGOSTINO BRUZZONE

Agostino Bruzzone since 1991, has taught "Theories and Techniques of Automatic Control" and in 1992 he has become a member of the industrial simulation work group at the ITIM University of Genoa; currently he is Full Professor in DIPTEM. He has utilized extensively simulation techniques in harbour terminals, maritime trading and sailboat racing sectors. He has been actively involved in the scientific community from several years and served as Director of the McLeod Institute of Simulation Science (MISS), Associate Vice-President and Member of the Board of the SCS (Society for Modelling & Simulation international), President of the Liophant Simulation, VicePresident of MIMOS (Movimento Italiano di Simulazione) and Italian Point of Contact for the ISAG (International Simulation Advisory Grouyp) and Sim-Serv.

FRANCESCO LONGO was born in Crotone (Italy), on February the 08th, 1979. He took the degree in Mechanical Engineering from University of Calabria (2002). He received the PhD in Industrial Engineering (2005). He is currently researcher at the Mechanical Department (Industrial Engineering Section) of University of Calabria and scientific responsible of the Modeling & Simulation Center – Laboratory of Enterprise Solutions (MSC-LES) in the same department. His research interests regard modeling & simulation of manufacturing systems and supply chain, DOE, ANOVA.