MODELING, SIMULATION AND OPTIMIZATION OF THE MAIN PACKAGING LINE OF A BREWING COMPANY

N. Basán [(a)], L. Ramos [(b)], M. Coccola [(c)], C. A. Méndez [(d)*]

[(a) (b) (c) (d)] INTEC (UNL - CONICET), Güemes 3450, 3000 Santa Fe, Argentina.

[(a)]basan.natalia@gmail.com, [(b)]ramos.lucila@gmail.com, [(c)]mcoccola@intec.unl.edu.ar, [(d)*]cmendez@intec.unl.edu.ar

ABSTRACT

Discrete event simulation (DES) techniques cover a broad collection of methods and applications that allow imitating, assessing and predicting the behavior of complex real-world systems. The main purpose of this work is to develop a novel DES model to optimize the design and operation of a complex beer packaging system in order to perform a sensitivity analysis to find one or more alternatives to increase productivity levels. In this way, advanced technologies of modeling, simulation and optimization for system design and operation are applied. The model is developed by using the DES tools provided by the SIMIO simulation software. The proposed tool is able to carry out evaluations of the system using a 3D user-friendly graphical interface that shows the dynamic evolution of the system over time. By using the proposed simulation model, the results of this paper illustrate how the levels of productivity may vary by reducing micro-downtime of machines, when transport rates and other problem features are properly changed with them.

Keywords: simulation, optimization, packaging line, brewing company

1. INTRODUCTION

In modern production processes, quality takes precedence in relation to production volume. A fundamental topic in market requirements is the product presentation. It implies that production lines need an additional number of machines to perform a wider variety of tasks. In this way, all activities must be conducted with the highest possible quality. Therefore, the growing demand and specialization in the presentation of the product make packaging lines more complex. More diversified tasks are performed on them.

This work arises from the need to identify, analyze and reduce the causes affecting the productivity of the main packaging line of an international beer company located in the province of Santa Fe, Argentina. Currently, the efficiency of the company's lines is lower than the level suggested by the managers. This situation has a directly impact on the current production level due to the packaging process is an essential step in the whole production process.

This work aims to optimize the design and operation of the main packaging line of the company in order to improve the global efficiency. In this way, a comprehensive simulation-based model was developed so that different future commitments and changing market conditions can be easily suited in the medium or short term.

2. METHODOLOGY

Having stated the general and specific objectives of the project, all the necessary data from the company under studying was collected by using five different techniques: (i) staff interviews, (ii) in-situ observation, (iii) historical data collection, (iv) reading manuals, and (v) review of equipment and transport.

Once the required information was collected, this one was analyzed, filtered and documented. Such procedure allows us to identify critical points and potential problems to be solved in the current and desired situation of the packaging process.

After understanding the real system that is subject of our simulation study, the conceptual model was developed. If we need to develop a model on a simulator, we need to determine the level of abstraction at which to work. This process of abstracting a model from the real world is known as conceptual modeling. For this particular project, SIMIO simulation software was chosen because this one allows to build animated models in three dimensions (3D), facilitating the verification and validation of the simulation model.

The inherent advantages of the simulation model developed were highlighted by solving three scenarios: (i) theoretical or ideal, (ii) current, and (iii) suggested scenario. A sensitive analysis had to be conducted to determine the more suitable alternatives regarding to the overall performance of the company, and consequently, the expected economical benefits.

2.1. Production Process

The beer production process comprises a series of manufacturing steps depending on the type of beer, varying the amount and type of raw material. Such steps are: malting, malt milling, mashing, cooking, wort cooling and clarification, fermentation, maturation, and the packaging process at the end.

2.1.1. Packaging Process

A packaging line involves a set of machines, equipment units and tools needed to perform the process operations. The success of the line depends on proper coordination of different elements. Similarly, in the case of a packaging line of a brewing company, beer and containers move through a series of processing stages until the final product is obtained. The flowchart is shown in Figure 1.

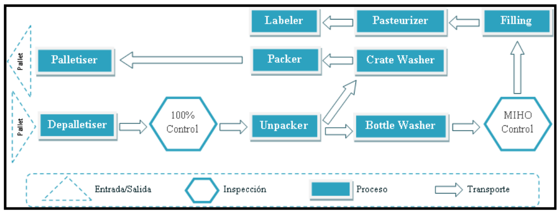

Figure 1: Beer packaging process

The first operation performed in a beer packaging line is depalletizing and disassemblying the pallet that comes from the deposit with empty bottles.

The next step, 100% control, aims to eliminate most of the waste entering with the drawers. This inspection is carried out manually by an operator. He removes items or bottles that could possibly harm the following machines.

Then, the process proceeds to perform the unpacking by a computer that has the function of extracting the empty bottles boxes that feeds the packaging line. The objective of the operation is to separate the drawer containers for subsequent washing operations on the respective machines.

After unpacking, the bottles are guided through the transport system to the washing process. Because all returnable bottles should be sanitized before being filled with beer again, the goal of this stage is to perform the physical and biological cleaning, removing all dirt, labels, adhesive and foil.

While we can assume that all bottles are dirt free in the washing machine, there is a risk this stage has not been able to completely remove all cleaning agents. Therefore, the output of this machine is a containers inspector.

Next, we proceed to perform filling and topped with beer in containers. The aim of the operation is to transfer product from a pot bulk and individual containers with airtight lids seal rolled steel to ensure durability, quality and inviolability of beer. Subsequently, through the process of pasteurization is achieved that beer is kept in ideal state at least until the date of minimum durability, i.e. the primary objective of pasteurization is to avoid possible biological decomposition and lengthen the bottled product.

The next step aims to place the labels presented in the final product. The labeling process begins when filled and capped bottles entering the labeling machine, and ends with a level-cap inspection rejecting bottles that do not meet any of the required characteristics in terms of filling level, internal pressure, and missing state missing labels and cap.

Once the bottle labeling operation is performed encased, which is contrary to the operation of unpacking. The machine is designed for gripping and moving sets of bottles into crates synchronously entering the computer.

Finally, we proceed to make palletizing, i.e. drawers are placed on a wooden stand known as pallet or pallet for easy handling and transportation future. The arrangement of the crates on the pallet is performed in layers according to a set distribution, in order to form a compact load unit capable of supporting stable after storage, transport and distribution.

On the other hand, different units are involved in the packaging process using transport. These are between the various machines in the line, providing a connecting element and synchronism between two of them. The rate is fixed by the same variable speed drives, and startup and shutdown is done by proximity sensor and optical detectors. The elements considered along the packaging process are pallets, crates and bottles.

2.2. Simulation Model

Process simulation is one of the most useful tools of industrial engineering, which is used to represent a complex process by another which makes it simple and understandable.

The proposed simulation model was developed by using the SIMIO programming package, which is one of the most specialized software in the area of process simulation that minimizes the risk and uncertainty in decision making, as well as minimizing the costs by improving the use of resources, reduced time spent and the minimization of the probability of risk.

Likewise, the packaging process involves five classes of modeling elements:

- Bottles that run the line
- Crates of bottles
- Machines that perform the operations necessary to prepare and process the product
- Transports located between different machines that make up the line
- Operators who have assigned different tasks.

2.3. SIMIO Simulation Software

SIMIO is modern flow simulation software for discrete event processes, and procedures based on objects. SIMIO allows conducting a simulation project in a much shorter time than usual. It is the first software that combines simulation modeling speed allowed by the object-oriented technology with the flexibility and power of procedures. This software enables the modeler to build animated models in three dimensions (3D) in one third of the usual time, and thus frees up time to devote to analysis of alternatives and scientifically informed decision-making.

Therefore, to model the packing process, it is necessary to represent the major components of the system, i.e. the products (bottles, boxes, pallets), machines, inspectors, transport and accumulation tables that form.

Different views of the simulation model of the main packaging line, developed in the SIMIO simulation software, are shown in Figures 2-4.

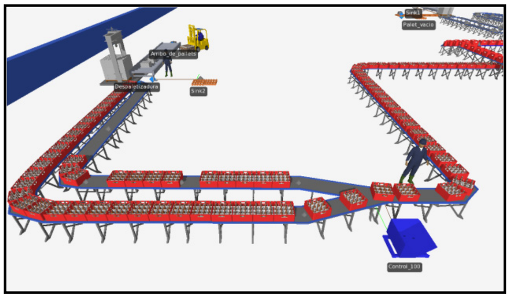

Figure 2: 3D SIMIO model (despalletizer)

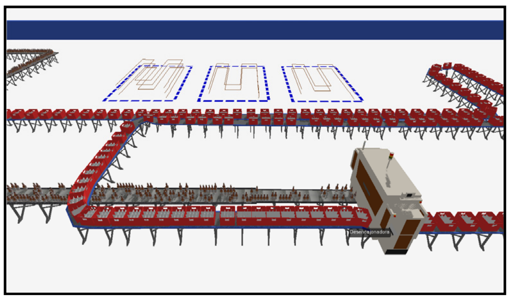

Figure 3: 3D SIMIO model (unpacker)

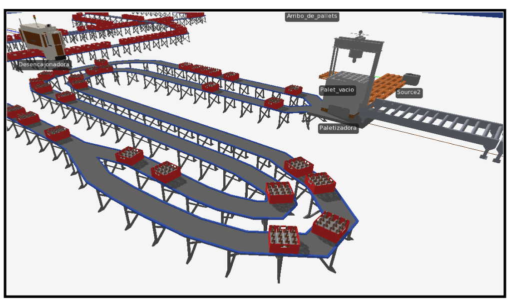

Figure 4: 3D SIMIO model (palletizer)

2.4. Creation of Simulation Model

For the creation of the simulation model, standard elements as source, process and sink were used, connected by a set of paths. The following components were identified in the real packaging line:

2.4.1. Pallets, Boxes and Bottles

As shown Figure 5, the dynamic entities moving through the system are: (i) pallets, (ii) drawers, and (iii) bottles.

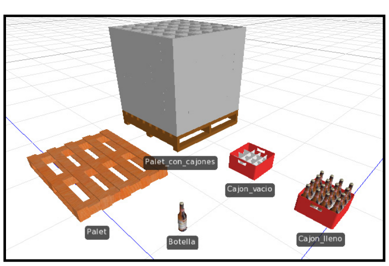

Figure 5: System entities

The "Source" module is used to create entities that arrive to the system. Figure 6 shows as pallet entity arrival is defined.

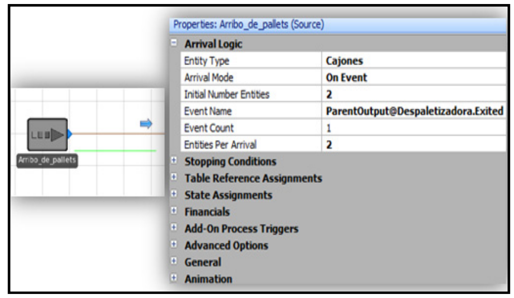

Figure 6: Pallet entity arrivals.

2.4.2. Depalletizer and Unpacker Machines

The depalletizer is the first equipment unit in the packing process. The module "Separator" provided by SIMIO is used to represent the depalletizer's operation, which is shown in Figure 7. On the right side of this picture, we can see the properties associated with the "Separate" module, i.e. the property "Processing Time" determines that each pallet is processed in a time of 50 seconds. Each pallet that is full of drawers enters to depalletizer to be processed and then 50 new entities representing the drawers are generated by the model.

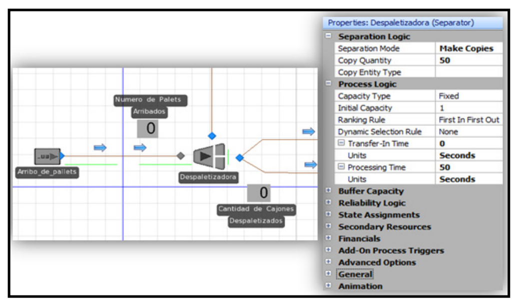

Figure 7: 2D SIMIO model (depalletizer machine)

The unpacker machine is modeled in the same way that depalletized equipment. Each drawer that is full of bottles enters to unpacker to be processed and then 12 new entities representing the bottles are generated by the model. Figure 8 shows the "Separator" module associated to the operation of unpacker unit.

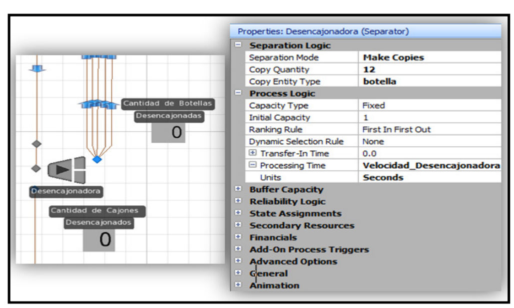

Figure 8: 2D SIMIO model (unpacker machine)

Between two operations describe above, there is an Inspection Process (Control 100%) that controls the drawers entering to the line. The representation in SIMIO of this process is shown in Figure 9. As we can see in the picture, a "Decide Step" that uses a probabilistic distribution is defined so that defective entities can be rejected.

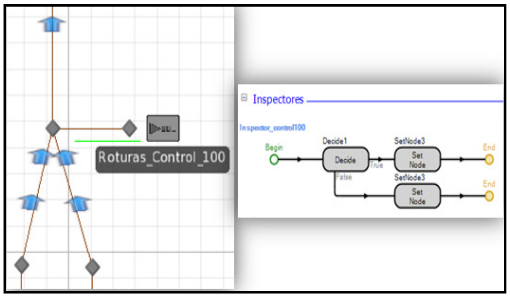

Figure 9: 2D SIMIO model (Control 100%)

2.4.3. Bottles Washer

This operation is built by placing 40 "Conveyor" objects in the SIMIO model. Each conveyor represents a real conveyor belt, which has a capacity of transporting until 710 bottles and a fix speed assuring that the bottles will be in the machine the minimum required time (45 minutes). Figure 10 shows the input/output logic of this stage.

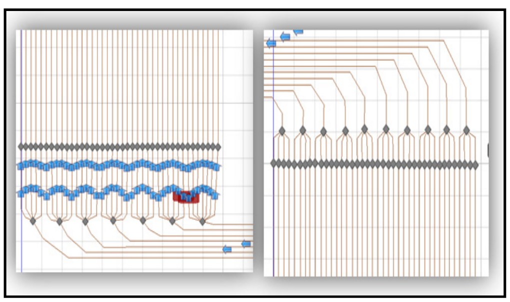

Figure 10: 2D SIMIO model (washing machine)

For the creation of the input logic to the washing machine, standard elements as events and timer were used. A group of 40 bottles enters to the washing process every 2 seconds

2.4.4. Empty Bottles Inspector

This stage aims to verify the bottles that previously have been processing in the washing machine. As shown in Figure 11, a basic node is used to represent this operation. Such node has one input path and three outputs path. The first output path receives the bottles that have a physical defect. The bottles that have some dirt are sent by the second output path. Finally, the accepted bottles continue their normal processing by the third output path.

2.4.5. Filling Machine

This processing stage is represented by a conveyor that has a transportation capacity of 154 bottles (equal to the amount of filling valves). The capping machine, which is then, has the same processing capacity too.

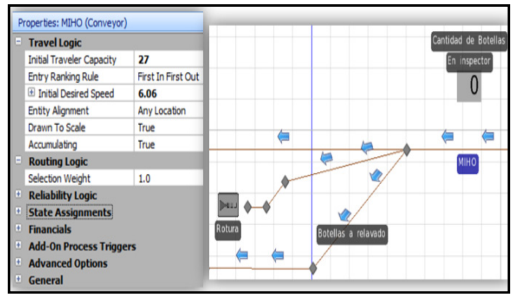

Figure 11: 2D SIMIO model (bottles inspector)

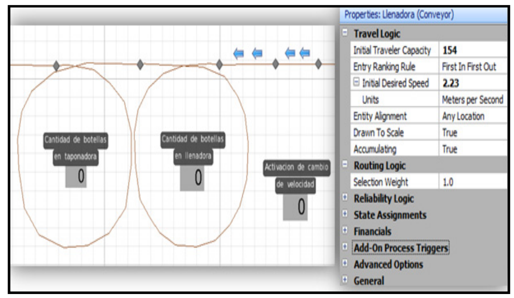

Figure 12: 2D SIMIO model (filling machine)

2.4.6. Pasteurizer Machine

The pasteurizing machine has two floors which were represented in SIMIO by 60 conveyors working in parallel (processed capacity of the equipment). In this stage, the bottles cross by "rainfall areas" that give water at different temperatures.

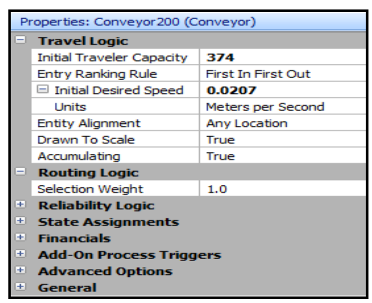

Figure 13: 2D SIMIO model (pasteurizing machine)

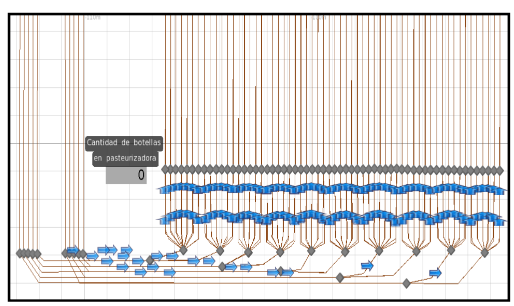

Figure 14: 2D SIMIO model (pasteurizing machine)

2.4.7. Labeler Machine

This equipment unit has an operation similar to the filler so that both processes were modeled in the same way (see Figure 15). Two inspectors look at the bottles to the end of this stage. This control process is defined similarly to Control 100% process described above. Besides, in order to compute the total amount of rejected bottles, two "Sink" component were used in the simulation model (HUEFT and FT_50).

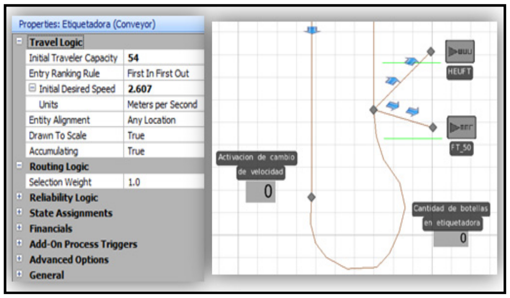

Figure 15: 2D SIMIO model (labeler machine)

2.4.8. Packer and Palletizer Machine

A "Combiner" module was defined in the simulation model to represent the behavior of the packer and palletizer machine (Figure 16 and Figure 17). In the first process, 12 bottles are assembled into a drawer. After that, the palletizer process puts together 50 drawers in a pallet (10 drawers per stack, 5 stacks per pallet). Then, the complete pallets are sent to storage modeled with a "Sink" module.

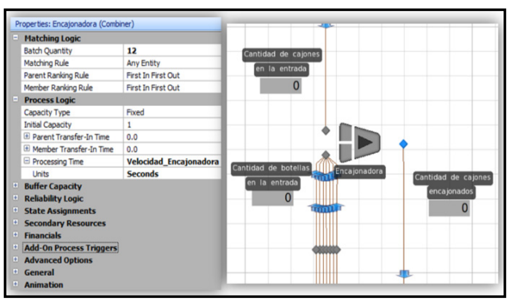

Figure 16: 2D SIMIO model (packer process)

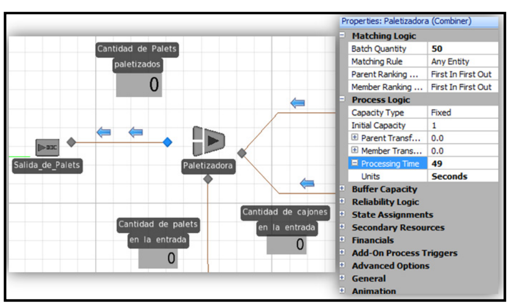

Figure 17: 2D SIMIO model (palletizer process)

2.4.9. Accumulation Tables

The accumulation tables ensure a constant supply of bottles or crates in the equipment that are after them. Since the machines are exposed to internal faults, these tables assured that if an equipment is broken, the rest of machines that are upstream can follow working.

On the packaging line there are three accumulation tables, two for bottles and one for drawers. The first accumulation table is located between the empty bottles inspector and the filling machine (see Figure 18). The second one is located between the pasteurizer equipment and labeling machine. Finally, the drawer accumulator is between the unpacker machine and the packer machine.

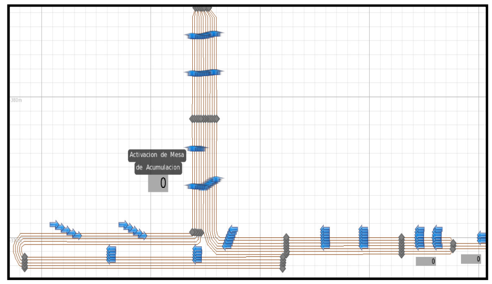

Figure 18: 2D SIMIO model (accumulation table for bottles)

Figure 19 shows as a "Monitor" element can be used to control the capacity of the conveyor that is above the accumulation tables for bottles. If the capacity of conveyor changes, a process called "Activar_Mesa" is trigger by the monitor.

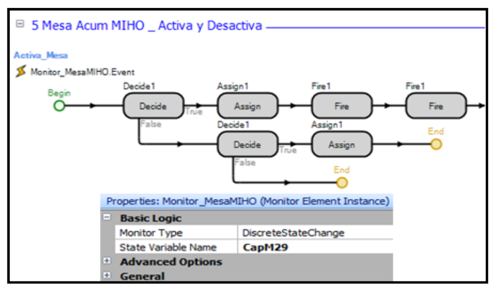

Figure 19: 2D SIMIO model (Monitor element)

In addition, a binary variable named "Activa_Mesa1" determines the current state of table 1. If the table is working, active_mesa1 is equal to 1; otherwise, it is set to zero.

Added to the above, the transport states located before or after of buffer are monitored. In this way, when table tapes are empty, the accumulating table is disabled by stopping transports and assigning a value of 0 to the associated binary variable. Figure 20 shows the monitor of one of the transports mentioned and the process associated with the deactivation of the buffer.

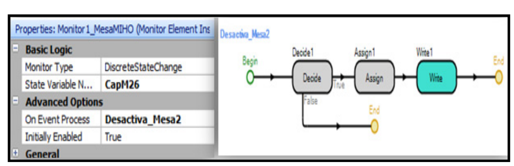

Figure 20: Logic associated with deactivating the first accumulation table

2.4.10. Drawers Combiners

On drawers transport line there are two combiners aiming to join two drawers belts into a single or reversely. The first combiner is located after depalletizer machine, more precisely where Control 100% is performed. Figure 21 shows as in this stage the two drawers lines are combiner into a single belt. On the other hand, the second combiner is situated before palletizer machine and its function is to divide the conveyor belt from the packer machine in two rows.

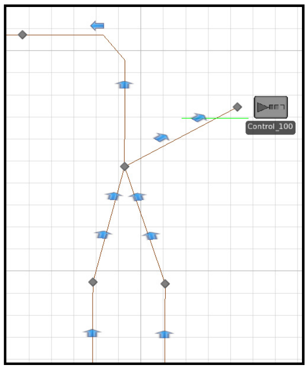

Figure 21: 2D SIMIO model (Drawers combiner)

Each combiner has a predefined logic, which is defined from processes and is associated with the transport involved. The first combiner transport has a longer length and other shorter length in parallel. So it allows passing more drawers with greater capacity in order to achieve a balance in the accumulation of the conveyors involved. It is worth to note that when one of them is moving, the other stops running.

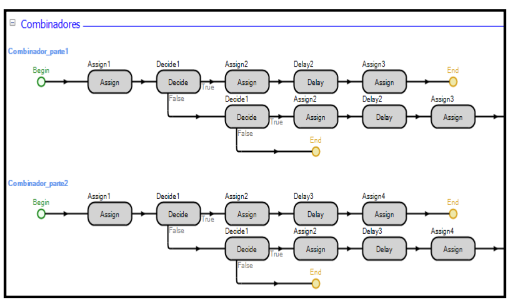

Figure 22: SIMIO processes

2.4.11. Transports

There are two transport lines, one for bottles and other for drawers. “Basic Node” and “Conveyor” elements were used in the simulation model to represent the two transport lines. It is worth to remark that some components of SIMIO have important parameters that must be set by the user. In particular, some “Conveyor” properties are given in Figure 23. From the picture, it follows that these properties might be used to vary things like conveyor speeds, traveler capacity, or the option for accumulating or non-accumulating conveyors

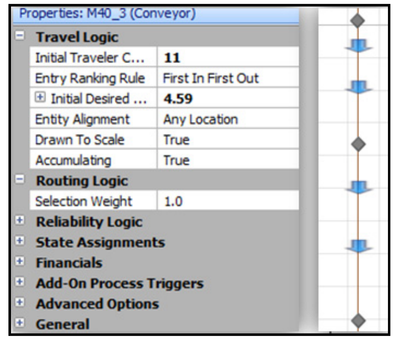

Figure 23: SIMIO simulation software (conveyor properties)

On drawers line there are only single conveyors. Instead, the bottle conveying line has conveyors of different widths. Thus, from one to ten bottles can be transported in parallel. An overview of this variable capacity transport is given in Figure 24.

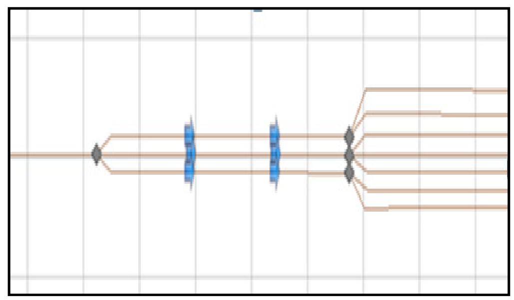

Figure 24: SIMIO simulation software (bottle conveying line)

In order to join transports with different carry capacities, several processes, whose logic is embedded within “Basic Nodes” elements, were defined in the simulation model (see Figure 25). Each process uses a discrete probability so that the bottles can be distributed on conveyors having available capacity. If any of the selected conveyors is on the limit of its capacity, other one in parallel must be chosen.

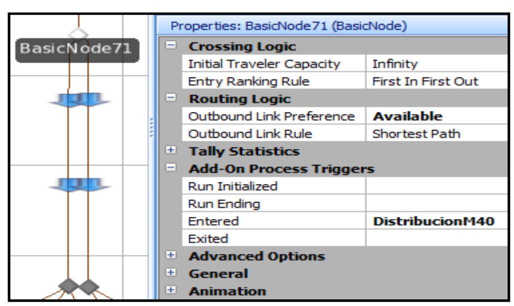

Figure 25: 2D SIMIO model (distribution processes)

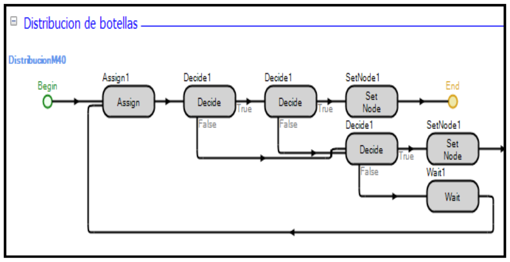

Figure 26: SIMIO processes (Bottles distribution)

2.4.12. Sensors

Several sensors control the number of bottles or drawers that are on the line. Such devices, located on strategic points of conveyor belts, emit signals so that transports or machines can start or stop their activities. These sensors are switches that are activated or deactivated according to whether they are in contact with the object.

To represent the above behavior, "monitor" and "variable" elements were used in the simulation model so that the logic of each machine can be properly defined. For example, the unpacker machine has three possible states: (i) stopped, (ii) low speed or (iii) high speed. A variable was defined to determine the machine state at a given time. The possible values of this variable are: 0 (if the machine is stopped), 1 (if the equipment is operated at low speed) or 2 (if the machine is running at high speed). In addition, three monitors were defined for associated transports. If a capacity change is detected in them, the monitors trigger a process determining the speed at which the equipment should operate. This value is then saved in a predefined variable. On one hand, if there is no accumulation in output transport and there are drawers in input transport, the machine operates at low speed. On the other hand, if there is accumulation in the input conveyor, the machine changes to high speed.

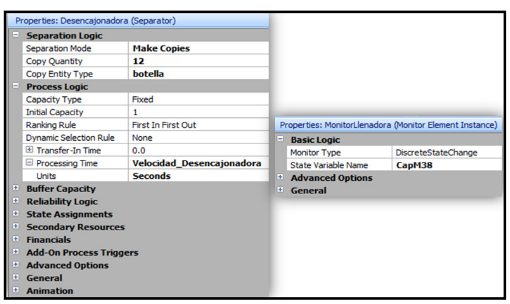

Figure 27: 2D SIMIO model (unpacker machine properties and accumulation monitor charecteristics)

2.4.13. Model Verification and Validation

In order to perform a verification of the simulation model developed, a detailed analysis of each packaging process operations was accomplished. This assures us that model logic properly represents the sequence of operations of the real process.

In addition, the model validation executes an iterative comparison with the real system, making the necessary adjustments and changes in the model until a satisfactory similarity is achieved.

2.5. Sensitivity Analysis

Therefore, after having identified the major operational problems, a series of changes is proposed to the design and operational model which a priori could increase the production capacity of the company, increasing the level of efficiency and address weaknesses the process. This alternative scenarios raised by changing the values of the factors considered most relevant.

- Scenario 1: system with engine capacities and speeds and actual transport, and percentages of rejections of inspectors,
- Scenario 2: system based on theoretical speeds of the machines, provided the design of the line ("V Line").
- Scenario 3: system considered in scenario 2, where, in addition, use is made of a battery drawer between the packer and unpacker machine,
- Scenario 4: system considered in scenario 2 with the modification logic combiner boxes found after the depalletizing machine,
- Scenario 5: system considered in scenario 2 with the increased transport speed that are in the area of the clean room due to the high rate of accumulation of bottles with those found before the empty bottle inspector .

Throughout the model, we adopt a series of measures for evaluating performance goals achieved by the line and compare its performance against changes that may occur. The proposed changes were modeled using the tools Ape presents the simulator and that were mentioned earlier. Thus, modifications were made on these variables, as they are directly related to the operation of the packaging line and determined the degree of improvement that can be achieved are effected once.

The performance parameters are considered for carrying out the analysis of the system is discussed below.

- Level of limiting Machine Efficiency: determining the average number of bottles processed in the filling machine, which is the limiting resource online, and is made by dividing this number and bottles should be processed in time modeling at the speed that is the filler,
- Effective Efficiency Indicator Global: determining the average number of bottles processed and is performed by dividing this number and bottles that should be processed in time modeling at the speed that is the palletizing machine,
- Load Factor of transport: checks during each work shift the percentage of occupation rate each conveyor involved in the process in order to modify those that have a high occupancy and gain stability in the entire packaging line,

- Number of pallets entered and graduated from the line: the purpose of this parameter is to determine the level of productivity that reaches the line under study for a work shift of eight hours,
- Changes in speed and stability of the machines: they want to reduce machine downtime seeking stability thereof thus explores the reasons why change their speed (or shortage of product accumulation) and proposes improvements.

3. RESULTS

The original design of line speeds under study is based on the concept of the "V" which takes the limiting speed of the machine, i.e. the filler, as a reference for defining machine speeds and hind to the same. The procedure for this calculation is carried out to increase between 10% and 15% speeds as they move away from the filler. Ideal speeds (assuming ideal speed machine bottleneck, 550 bpm) and actual speeds of the machines (considering uptime, downtime and uptime internal) over a month of work were considered. Table 1 and Table 2 show the results obtained from the analysis of speeds detailed above.

Table 1: Analysis of theoretical speeds

	Theoretical Speeds	
Machines	Machines Speeds (bph)	Percentage of capacity limitation machine
Depalletiser	43.260	40
Unpacker	40.170	30
Washer	35.535	15
Filling	30.900	0
Labeler	35.535	15
Packer	40.170	30
Palletizer	43.260	40

Table 2: Analysis of actual speeds

	Real Speeds		
Machines	Machines Speeds (bph)	Percentage of machine capacity preceding	Percentage of capacity limitation machine
Depalletiser	40.440	-9,7	30,9
Unpacker	41.820	8,9	35,3
Washer	38.400	24,3	24,3
Filling	30.900	0,0	0,0
Labeler	36.000	16,5	16,5
Packer	38.160	6,0	23,5
Palletizer	40.740	6,8	31,8

The data in the table are expressed in Figure 28 for a better visualization. It can be seen that the concept of the "V" approaches the ideal nearby machines in the filler, but not at the ends.

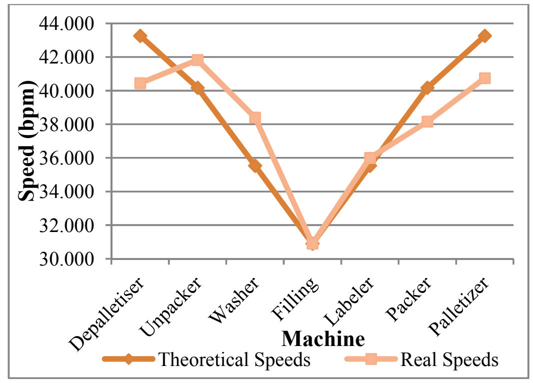

Figure 28: "V" line with ideal and actual speeds

Furthermore, the company determines the productivity of the packaging line from the measurement of the efficiency of their equipment. This is calculated from the values corresponding to the number of bottles produced during an operating period determined in relation to the theoretical amount of bottles that must have occurred during that period (Equation 1). The bottles theoretical amount calculated from the limiting speed of the line which, as mentioned above belongs to the filling machine.

$$Efficiency = \frac{Actual\ number\ of\ bottles\ produced}{Theoretical\ Number\ of\ bottles\ produced} \quad (1)$$

For this calculation, reports were consulted production of 3 consecutive months, of which we obtained the total production time and the volume produced in the same. Thus, Table 3 shows in greater detail the productivity of each month analyzed. From efficiency values shown in the above table is obtained in the same behavior and the present trend in time (Figure 4). Therefore, we can determine that the line has a 66.76% average productivity.

Table 3: Productivity Data

Month	Week	Actually produced bottles	Theoretical produced Bottles	Average efficiency
1	1°	3.187.638	4.752.000	67,58
	2°	3.079.862	4.752.000	
	3°	3.269.809	4.752.000	
	4°	2.985.746	4.752.000	
2	1°	3.082.036	4.752.000	66,55
	2°	3.041.290	4.752.000	
	3°	3.424.400	4.752.000	
	4°	3.054.792	4.752.000	
3	1°	3.155.279	4.752.000	66,17
	2°	3.069.707	4.752.000	
	3°	3.245.196	4.752.000	
	4°	3.108.242	4.752.000	

In this way, the efficiency of the model created can be compared with the one of real system. Actually the company has a line efficiency of 66.77%, which is similar to the obtained by the simulator because it reports a 66.8% value.

In addition, the following productivity indicators were used in order to validate the simulation model developed: (i) number of pallets produced by shift (in both the feed and outlet line) and (ii) production in each machine.

The simulation model developed was executed several times to obtain performance mean values. The information obtained is then compared with historical data of the line. This comparison is showed in Table 4.

Table 4: Performance measures of the real system vs the simulation model

Machine	Real System (pallets per turn)	Simulation Model (Pallets per turn)
Despalletiser	283	282
Empty bottle inspector	280	278
Filling	277	275
Labeler	272	268
Packer	278	274
Palletiser	271	270

Having analyzed all data from many runs, we conclude that the simulation model developed has acceptable apparent validity.

Having analyzed the most relevant scenarios, presented above, key performance measures achieved in each of them are summarized in Table 5 and Table 6. Therefore, it is possible concluding that scenario 5 achieves the highest level of efficiency in terms of the bottleneck resource and also the highest level of overall effective efficiency. This results in a remarkable increase in the production of a rolling line and the use of machines and transports.

Table 5: Summary of results obtained

Scenario	Processed in filling bottles	Processed in bottles depalletiser	Processed in bottles Palletizer
1	165.059	157.200	151.800
2	161.375	160.200	154.200
3	161.512	162.000	155.400
4	177.462	178.800	175.200
5	206.200	211.200	204.000

Table 6: Summary of efficiency indicators

Scenario	Percent Efficiency	Effective Global Efficiency
1	66,8	61,4
2	61,1	58,4
3	61,2	58,9
4	67,2	66,4
5	78,1	77,3

Consequently, a 11.4% increase can be achieved in efficiency by implementing minor changes without incurring large investments while achieving significant improvements in the operation of the line associated with an increase in company profits.

It is noteworthy that the developed simulation model can be easily used for the evaluation of alternative scenarios, i.e. the analysis of proposals for possible future changes in the design and operation of the line.

4. DISCUSSION

The decision variables allowing increasing both the efficiency of the bottleneck machine and the efficiency of the overall line are the speeds of the machines that make up the transport and packaging process as well as the logic conditions programmed in the units.

Furthermore, it is considered that these efficiencies are less sensitive against increasing line capacity drawer, which is associated with an accumulator device for drawers or operator responsible for the same task.

Short stops primarily derived from simple causes can be reduced drastically without complex operations on the machines, although there are also small stalls that can only be removed using sophisticated methods of analysis and operations with high technical content.

The causes that affect the productivity of the packaging line, according to the simulation model carried out, is the modification of the logic of the carriage of the feeding of the packaging process and clean room. Furthermore, the line is sensitive to changes in the speeds of the machines, which are operating at a speed below the nominal speed.

It is noteworthy that for fixed values of speed and transport machines, no investment is needed by the company, because they have the materials and labor necessary for the modification of the same drivers.

Moreover, the study remarks that not always increasing the efficiency ratio on a particular machine line, from the reduction of a kind of loss, produces an increased rate of overall line efficiency. This is because the relationships and interactions in the real system are complex or some degree of uncertainty is present.

It has been essential to have the automatic registration of faults, without which no one could have calculated the time lost in stops. On the other hand, it would be beneficial to all line stoppages would be assigned automatically and easily exported to a spreadsheet. This would avoid much preparation work and subsequent data analysis.

ACKNOWLEDMENTS

Financial support received from ANPCyT under grant PICT-2010-1073, from CONICET under Grant PIP-2221 and from UNL under Grant PI-66-337 is fully appreciated.

REFERENCES

Banks J., Carson J.S., Nelson B.L., Nicol D.M., 2004, *"Discrete-Event System Simulation"*; 4th. Ed.; Prentice-Hall U.S.A.

Christel, M.; Kang, K., 1992, *"Issues in Requirements Elicitation"*, CMU/SEI-92-TR-012, Pittsburgh, EE.UU., Software Engineering Institute, Carnegie Mellon University.

Fishman George S., 1978, *"Conceptos y Métodos en la Simulación de Sistemas Discretos"*. Limusa México.

Gordon Geoffrey, 1981, *"Simulación de sistemas",* 2da. Ed., Prentice Hall, México.

Hepp, P.K.; *"Introducción a la Adquisición de Conocimiento para Sistemas Expertos"*.

Hines W. W., Montogomery D. C., 1990, *"Probability and Statistics in Engineering and Management Science"*, 3rd. Ed., Wiley, New York.

Kelton D., Sadowski, R.P., Sturrok, D.T. 2006, *"Simulation With Arena"* Fourth edition. McGraw-Hill series in Industrial Engineering and Management Science.

Kuo Benjamin; 1975, *"Automatic Control Systems"*; 3rd Ed.; Prentice-Hall, U.S.A.

Law Averil, Kelton W. David; 1991, *"Simulation Modeling and Analysis"*; 2nd. Ed.; McGrawHill, Inc., U.S.A.

Mazzieri G., Obeid Z., 2004 *"Distribución de Mercaderías en Áreas Urbanas desde un Depósito Central"*. Dpto. de Ing. Industrial, Fac. de Ing. Química, Univ. Nac. del Litoral.

Musselman K, 1998, *"Guideliness for Success"* en *"Handbook of Simulation. Principles, Methodology, Advances, Applications and Practice"*. Banks J. Editor. John Wiley & Sons, Inc., USA.

Naylor Thomas, Balintfy Joseph, Burdick Donald, Chu Kong; 1991, *"Técnicas de simulación en computadoras"*; Editorial Limusa, México.

Papoulis Athanasios, 1990, *"Probability and Statistics"*, Prentice Hall, Englewood Cliffs, N.J.

Piattini M., Calvo-Nanzano J., Cervera J., Fernández L., 1996, "*Análisis y Diseño Detallado de Aplicaciones Informáticas de Gestión"*. R. A. M. A. Editorial, Raghavan, S.; Zelesnik, G.; Ford, G.: "Lecture Notes on Requirements Elicitation", CMU.

Renee Thiesing, Christine Watson, Judy Kirby, David Sturrock, 2009, *"SIMIO Reference Guide"*. Versión 2.0.

Ross Sheldon M., 1993, *"Introduction to Probability Models"*, 5th. Ed., Academic Press, N. Y.

Sapag Chain N., Sapag Chain R. 1989, *"Preparación y Evaluación de Proyectos de Inversión"*. Mc. Graw-Hill.

Senn, J.A., 1988, *"Análisis y Diseño de Sistemas de Información",* McGraw-Hill.

Shannon, Robert; 1988, *"Simulación de Sistemas. Diseño, desarrollo e implantación";* Trillas, México.

Walpole Ronald, Myers Raymond, 1989, "*Probability and Statistics for Engineers and Scientists"*, 4th. Ed., Macmillan, N.Y.

AUTHORS BIOGRAPHY

NATALIA BASAN is an Industrial Engineer and PhD student conducting research in hybrid optimization & simulation tools for production planning and scheduling of automated production systems.

LUCILA RAMOS is an Industrial Engineer conducting research in hybrid optimization & simulation tools for production planning and scheduling of automated production systems.

MARIANA COCCOLA is an Information Systems Engineer and a PhD student conducting research in hybrid optimization & simulation tools for production and logistics systems.

Dr. CARLOS A. MENDEZ is a Titular Professor of Industrial Engineering at Universidad Nacional del Litoral (UNL) in Argentina as well as a Researcher of the National Scientific and Technical Research Council (CONICET) in the area of Process Systems Engineering. He has published over 150 refereed journal articles, book chapters, and conference papers. His research and teaching interests include modeling, simulation and optimization tools for production planning and scheduling, vehicle routing and logistics.