A SIMULATION-BASED TOOL TO SUPPORT DECISION-MAKING IN LOGISTICS DESIGN OF A CANS PACKAGING LINE

Victoria G. Achkar[(a)], Valentina Bär[(b)], Franco Cornú[(c)], Carlos A. Méndez[(d)]

[(a),(d)] INTEC (UNL – CONICET), Güemes 3450, 3000 Santa Fe, Argentina
[(b),(c)] Facultad de Ingeniería Química, UNL, Santiago del Estero 2829, 3000 Santa Fe, Argentina

[(a)]vachkar@intec.unl.edu.ar, [(b)]valentinabar.26@gmail.com, [(c)]cornufranco@hotmail.com.ar, [(d)]cmendez@intec.unl.edu.ar

ABSTRACT
This paper proposes an advanced discrete-event simulation-based tool developed in order to support decision-making in the design of internal logistics associated to a packaging line of a multinational brewery company. The selected software, SIMIO, allows emulating, advising and predicting the behavior of complex real-world systems. It also provides a modern 3D interface which facilitates the verification and validation of the model. In this work, it is used to understand the dynamic interactions between multiple performance measures (including both material-handling and inventory system performances) to help defining necessary quantities and capacities associated to a future cans packaging line. Based on the proposed model, a what-if analysis is performed to determine thresholds values and critical variables in order to optimize the current system.

Keywords: discrete-events simulation, packaging line, logistics, design

1. INTRODUCTION

Due to increased logistic costs associated to returnable beer bottles, in the last years, an important brewery company decided to introduce cans package into the local market in order to reduce the consume of the mentioned bottle format. The main goal is to make savings related to inverse logistic costs and to optimize transport carrying a bigger amount of beer in the same vehicle, inducing a change in customer habits. This strategic decision conduces to necessarily increase production capacities in its factories or indeed to install new packaging lines. Strategic decisions in manufacturing systems typically concern design problems and resources allocation in the medium/long period. Usually, problems at this level may involve contrasting objectives therefore requiring a strong experience (for people involved in the decision process) as well as advanced decision support tools. (Bruzzone and Longo 2013). They also have a strong impact concerning financial issues. This work focuses on the design of a new cans packaging line. It aims to support decision-making to ensure the best configuration of internal logistics, including storage and materials-handling, to avoid incurring in additional costs.

To address this kind of issues (representation and optimization design and operation processes), there are two solution strategies typically used: (i) mathematical analysis and (ii) simulation. There are many reasons for using the first strategy opposed to the second one (Seila, Ceric and Tadikamalla 2003). For example, the system under study may yield a model that is so complex that it cannot easily be described using this method. Using mathematical analysis may leave the options of either further simplifying the model and perhaps making it unrealistic or using simulation.

Manufacturing and material-handling systems provide one of the most important applications of simulation. It has been used successfully as an aid in the design of new production facilities, warehouses, and distribution centers. Engineers and analysts using simulation have found it valuable for evaluating impact of capital investments in equipment and physical facility of proposed changes to material handling and layout. Managers have found it useful in providing “test drive” before making capital investments, without disrupting the existing systems with untried changes (Banks, Carson, Nelson and Nicol 2005).

In consequence, discrete events simulation methods are adopted to represent the whole real-world process as an integrated form. The simulation mode, developed with SIMIO software, is used to accurately represent future process operation in order to analyze its behavior with its critical variables, mainly those associated to storage and material-handling. The goal is to evaluate the feasibility of getting the desired production capacity and at the same time trying to optimize internal logistics resources. Therefore, different scenarios are created varying production schedules, to also aid verification and validation processes. Other works has recently used this modern tool to solve similar situations in decision-making processes (Achkar, Picech and Méndez 2015; Aguirre, Müller, Seffino and Méndez 2008; Basán, Cóccola and Méndez 2015).

The work continues with the following structure: (ii)methodology, (iii)internal logistics system (iv)simulation model, (v)verification and validation, (vi)sceneries and experimentation (vii)conclusions.

2. METHODOLOGY

To address the problem by modeling and simulating the system, several steps must be taken to create an accurately model that reflects the real system. The following steps were taken: (i)information collection, (ii)data analysis, (iii)conceptual model definition, (iv)simulation model developing, (v)verification and validation, (vi)scenarios definition, (vii)results analysis.

The first step consists in collecting accurate information from the system to start comprehension process and to take into account every component that could influence. Different techniques were applied on this stage: (i)collection of historical data and daily records, (ii)"in situ" observation and time keeping, (iii)iterative interviews with personal involved.

One part of the information obtained is used to fully understand the problem and generate the conceptual model. The conceptual model is used to obtain a sufficient abstraction level of the problem and to define assumptions. The other part of the information is filtered and analyzed to become input data. Truck types and their arrivals, materials rejection rates, packaging speed, resources efficiency, forklift characteristics, warehouses operation rules and capacities, among other factors, are studied in this step.

The fourth step is to create the simulation model on the basis on the information gathered and the conceptual model. SIMIO, the software chosen, is a simulation modeling framework based on intelligent objects. A model is built by combining objects that represent the physical components of the system (Thiesing, Watson, Kirby and Sturrock 2015). These objects could be forklifts, pallet of materials, warehouses, packaging lines, trucks, racks, etc. We choose SIMIO for its power to represent the system in three dimensions and to model realistic spatial relationships of layout. This results in a user friendly interface that facilitates model verification and validation.

Once the simulation model is completed, verified and validated, it is used to analyze critical performance variables and represent scenarios with desired operational policies, evaluating system feasibility and defining necessary level resources such as quantity of forklift or stock area capacities.

3. INTERNAL LOGISTICS SYSTEM

The packaging sector has relationship with different areas of the company, such as logistics, warehouses, maintenance, quality control, etc. These sectors perform simultaneously different tasks and depend on each other for proper operation. This work features on two of them: warehouses and internal logistics. The last one manages raw materials and final products through the plant, using forklift belonging to different sectors. High season is a critical period due to intense material flows between all sectors. Final product dispatches and truck arrivals are also in charge of this sector.

Warehouses are used to stock final products, raw materials and inputs. Packaging is an internal client of them, requesting for bringing raw material and inputs depending on its needs, and carrying final products.

The following picture presents the main sectors involved in this problem with the flow of materials.

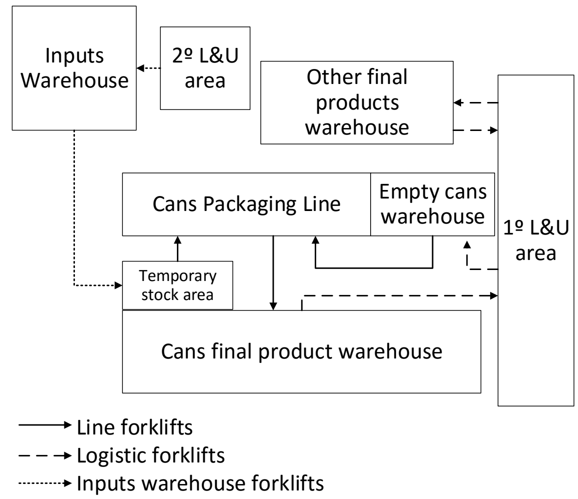

Figure 1: Sectors and material flow involved in internal logistics of the cans packaging line

As shown, the system includes (i)a packaging line, (ii)four warehouses, (iii)one temporal stock area and (iv)two loading and unloading (L&U) areas. Components of the system are descripted below.

3.1. Forklifts

In the plant there already exist five forklifts that are related to the system under study: four logistic forklifts and one exclusive forklift for the inputs warehouse. There are still no line forklifts (neither packaging line). All of them have the same speed, loading and unloading times, but not same carrying capacities. They also have different work schedules, breaks and assigned tasks depending on the sector each one belongs. They perform different tasks carrying pallets through the system as it is shown in the previous picture. In Table 1, some characteristics of every type are listed.

Table 1: Forklifts characteristics

Type	Quantity	Capacity	Work Schedules
Logistic	4	2	Sunday 20hs to Saturday 5hs
Input warehouse	1	1	Monday 0hs to Friday 17hs
Line	0	1	24hs

3.2. Materials

There is a wide variety of material moving through the system. To produce a pallet of final product, ten different inputs are needed, such as empty cans, can lids, different types of cartons, wraps, stickers, ribbons, etc. Most of them are packaged in pallets. There are also intermediate material pallets and scrap traveling through the system.

3.3. Trucks

On the one hand, trucks enter to the principal L&U area to load final products and to unload empty cans. They also make loads and unloads related to other packaging lines. On the other hand, trucks entering to the secondary area unload inputs to stock them in its exclusive warehouse. Most of them can transport 24 pallets, except for those transporting empty cans that transport 22 pallets. Depending on the type of truck, there could be different restrictions to enter into the factory.

3.4. Packaging Line

The future packaging line is wanted to work 24 hours a day, 3 to 7 days a week depending on the season.

The expected line speed rounds 80,000cans/h and its efficiency is about 75%. Input consume rates are given by a bill of materials and there is a temporary stock area nearby for immediate supply. This temporary stock area will have defined replenishment frequency and a fixed capacity to define. The output of the line also has a maximum capacity. Forklifts are expected to store final products, feed the line and perform secondary tasks associated to residual input pallets that must be returned to suppliers.

3.5. Warehouses

There are three principal warehouses of interest in the system: input, empty cans and final product warehouses. Each of them have desired security stock levels. Inputs warehouse has the same work schedule as its exclusive forklift previously mentioned. On days off, it must ensure that the temporary stock area has enough quantity of material to avoid interrupting the production. The remaining warehouses are directly related to de packaging line, so they must be able all the time.

3.6. Loading and unloading areas

The principal L&U area has four parking places. There, trucks bringing and retiring materials of all packaging lines share this parking places. Focus on tasks related to packaging line, empty cans pallets are unloaded to be stored in its correspondent warehouse. Only one truck of this type can enter at a time. An analyst examines the lot of empty cans and decide of the truck is rejected or not. About 5% of these trucks are rejected (empty cans is a very fragile product). Trucks that arrive to load cans final product has no entrance restrictions.

The secondary L&U has a single parking place and most of the tasks performed are unloading input pallets for all the packaging lines. Inputs warehouse forklift is in charge of this area.

3.7. Problem definition

Once all components and their interactions are fully understood, different conflicts can be detected. There must be a coordinate relation between every sector. Variations on the line speed or on its work schedule will directly impact on warehouses occupation rates. The line could need to be replenished and to retire final product with variable frequency and will consequently impact on line forklifts utilization. Furthermore, final product warehouse will tend to get full during operational days and empty when the line is not working, and in a similar way empty cans warehouse and input temporary stock area occupation rates will vary. To deal with the situation, the number of daily trucks must increase, both to bring inputs and to dispatch final product. Consequently, logistic and input warehouse forklifts are immediately affected. Moreover, security stock levels should be reconsidered, taking into account capacity limitations.

This work analyzes the possibility of getting the desired speed and work schedules without collapsing the system. Trucks arrivals must be designed according to final product desired sales volume and to guarantee certain stability in warehouses occupation. Security levels will be set according to line speed and to support a desired number of days of production. Temporary stock area must be dimensioned according to desired replenishment frequency. Line forklifts optimal quantity must be proposed and also if any forklift must be added to other sectors. Parking places will be evaluated to determine if they can deal with the amount of trucks entering into the system. The simulation model must give enough information to make this set of decisions.

4. SIMULATION MODEL

Once the system is completely understood, the next step is to develop the simulation model. SIMIO makes modeling dramatically easier by providing a new object-based approach. Objects represent the physical components in your system such as workstations, conveyors, and forklift trucks in a manufacturing facility. Object-based modeling is a very natural and simple approach to simulation modeling (Pedgen 2009). The developed model uses a factory scale plan with representative distances. The following subsections describe the major components of the model.

4.1. Model assumptions

The major assumptions made in the model are listed below:

- The efficiency of the line is traduced in a daily productive period of time with constant production speed.
- A generic cans product was defined pondering both existing sizes according to its sells. A pallet of this generic product contains 2280 cans.

- Final product pallets are immediately stored in its warehouse and the output of the line has a limited capacity.
- Temporary stock area can store all pallets that are brought to it, and it has defined replenishment frequency.
- Every sector and forklift has a defined work schedule.
- Every truck transports exclusively one type of material.
- Only trucks transporting empty cans have entrance restriction: one at a time.
- Trucks have defined capacities according the material it transports.
- Forklifts do not fail and drivers do not absence (in real system there is an additional forklift ready to supply any of them).
- Trucks are loaded/unloaded using at maximum three forklifts.
- Line forklift does never stop working (drivers take turns to replace).

4.2. Input variables

Some variables are entered in the model as input data, and others are decision variables.
On the one hand, the main variables are:

- Truck characteristics (capacities, rejection rates, entering restrictions, etc.).
- Forklift characteristics (capacities, speed, work schedules, L&U times).
- Packaging line speed.
- Replenishment frequency and quantities of the temporary stock area.
- Bill of materials.
- Quantity of pallets that can be accumulated at the output of the line.
- Secondary task characteristics.
- Line efficiency (traduced in productive and unproductive daily periods of time).

On the other hand, decision variables are:

- Line work schedule.
- Quantity of forklifts.
- Arrivals of trucks.
- Security and initial stock levels.
- Restocking frequency to temporary stock area.

4.3. Output variables

The main variables used to measure the performance of the system are:

- Total production.
- Quantity of line interruptions because of the lack of inputs.
- Average, maximum and minimum stock levels of each material in warehouses.
- Average, maximum and minimum stock levels of each material in the temporary line stock area.
- Total number of trucks arrived and total number of trucks attended.
- Forklifts and parking places utilizations.
- Average and maximum stock levels in the output of the line.

Analyzing the values of these variables allows detecting if any restriction is not been accomplished or if the model collapsed.

4.4. SIMIO Model

The computer model was made using different objects provided by the software and setting its properties to adapt them. For further customization, internal logic processes where created and associated to different objects. These processes allows, using events, states, monitors, timers and other definitions of SIMIO, modeling every detail necessary to create an accurately system representation. For example, entrance restrictions, rejection rates, material routes and destinations and requests of materials were modeled with internal logic processes. Appendix A has a small glossary including the major objects of SIMIO used in the model.
How the major components of the system were modeled is described in the following subsections:

- Pallets of materials and trucks: were represented using entities, with different priorities to differentiate them.
- Forklifts: using the vehicle object, they were modeled introducing its characteristics such as speed, capacity, L&U times, etc. Figure 2 shows trucks, pallets and forklifts of the model. Objects animation facilitates to identify each one.

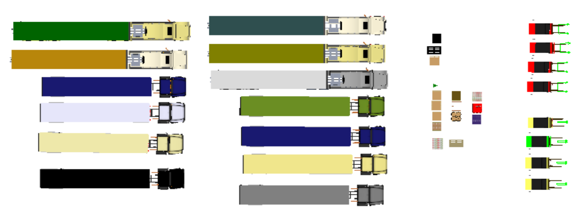

Figure 2: Trucks, pallets and forklifts objects in 2D SIMIO model

- Cans packaging line: it was represented using several objects. The main one is a Workstation object. It contemplates consumption and production rates defining a BOM (Bill of materials) matrix. It has monitors with threshold values defined to request input pallets when they are crossed. Figure 3 shows the packaging line at right and the temporary stock area at left.

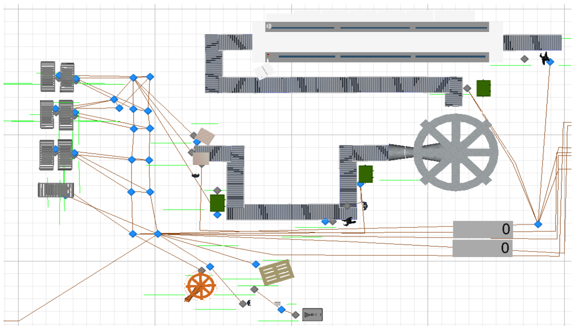

Figure 2: Packaging line and temporary stock area in 2D SIMIO model

- Warehouses: were modeled with server objects for each kind of material, customized using internal logic processes to retain pallets until they are requested from another sector and liberate the exact requested quantity. They also have monitors that control stock levels. Figure 3 presents empty line (left) and cans final products (right) warehouses.

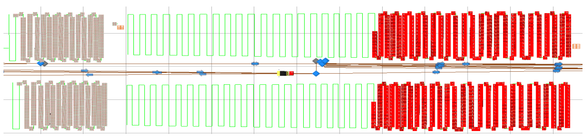

Figure 3: empty cans and cans final product warehouses in 2D SIMIO model

- Temporary stock area: modeled with server objects, they work similar to warehouses, with the difference that it has not a defined capacity (it must be determined as a model output).
- L&U areas: they were also represented with server objects, one for each parking place. These sectors uses a big quantity of internal processes, to model every restriction, rejection rate, setting entities destination or requesting warehouses to bring them depending on the type of truck. In Figure 4 there is the input warehouses conformed by several server objects and at left there is the secondary L&U area.

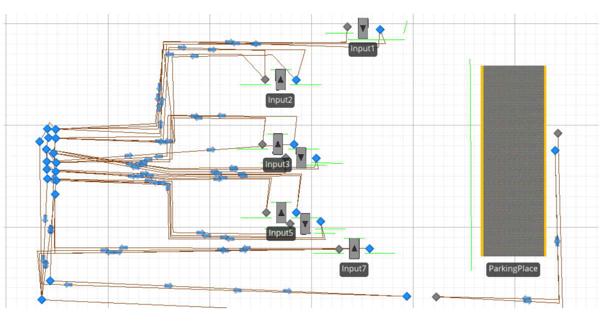

Figure 4: inputs warehouse and secondary L&U area in 2D SIMIO model

The figure below shows a global view of the animated model. Each sector with its elements can be easily identified, and their operation and interactions can be simultaneously watched.

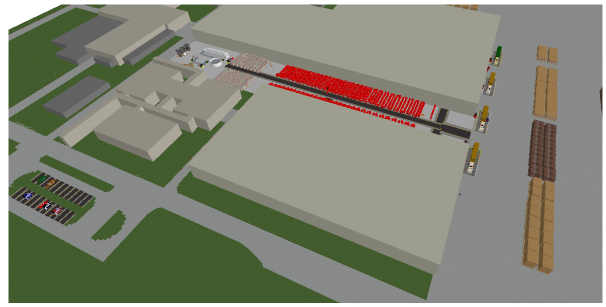

Figure 5: Global view of the 3D SIMIO model

5. VERIFICATION AND VALIDATION

Verification is concerned with determining if the conceptual model with its specifications and assumptions were correctly traduced in computerized representation (Law Averil 2007). During the conceptual model development, several requirements of the different elements were determined, concerning expected values and system behaviors, such as production rates and arrival rates, restrictions of entry and operation, etc. The expected values were compared with output variables thrown by the simulator. Figure 6 shows a comparison between empty cans trucks required to satisfy the production in the conceptual model and those arrived on the simulated system. Then, Figure 7 presents estimated monthly production rates versus the output from the model. Similar values prove that the behavior of the computer model is in accordance with estimated values.

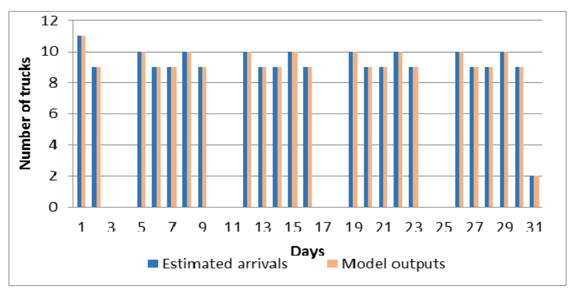

Figure 6: Empty can trucks arrivals verification

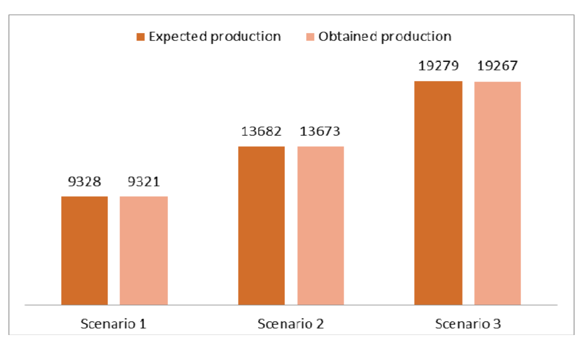

Figure 7: Monthly production verification

Therefore, validation was carried out, which is concerned with determining how closely the simulation model represents the real system (Law Averil 2007). In this step, several iterative comparisons between output variables obtained by the simulator and information gathered from the company are performed. The most difficult aspect in this step consist in validating a line which does not exists yet. Thus, there are many aspects that cannot be compared with a real model. To carry out validation, some aspects were taken from resources that exists in other lines in the same plant. Form example: forklifts times to perform tasks and permanence times of trucks in parking places. Distances that must be covered by forklifts and trucks in the simulation model were compared with the real scale plant layout provided by the company. Other aspects were validated using as reference another cans packaging line belonging to the same company, such as times related to secondary tasks and inputs consumption rates. Finally, all aspects were discussed with experienced staff from the company. In each iteration, changes and necessary adjustments are made on the model programming in order to achieve the desired values.

6. SCENERIES AND EXPERIMENTATION

As a result of the seasonal demand characteristic on this kind of enterprises, it was imperative to analyze three types of operational configuration for the can packaging line. The scenarios evaluated were:

- *Type 1:* 4 operational days during the first week, 4 operational days in the second and 3 operational days in the third.
- *Type 2:* 5 operational days of the line during the week.
- *Type 3:* 7 operational days of the line during the week.

Due to each scenario has a different work schedule but packaging speed keeps constant, it was necessary to define for each of them an exclusive policy of operation. The main variables affected were: (i)packaging line work schedule, (ii)daily trucks arrivals, (iii) forklifts quantities, (iv)restocking frequency to temporary stock area and (v)maximum quantity admissible of other truck arrivals. The simulation period is a month. Table 2 shows a description of every scenario, with major decision variables involved. Each scenario has defined the same quantity of forklifts: 4 for logistics, 3 for the line and 1 for the inputs warehouse. Then, Tables 3 and 4 show the results of principal output variables. Maintaining the same quantity of resources available, the company wanted to know the number left of arrivals that they can use per day to attend other lines. The maximum daily arrivals of other trucks admissible keeping the same quantities of forklifts for each scenario are: 117, 113 and 80 for types 1, 2 and 3 respectively.

Table 2: Scenarios decision variables

Scenarios: Decision variables				
Sceneries	Packaging line work schedule	Empty cans trucks	Final product trucks	Inputs trucks
1	Type 1	141	389	28
2	Type 2	207	572	38
3	Type 3	291	804	53

Table 3: Maximum stock levels to measure warehouses

Sceneries	Max. stock level in empty cans WH	Max.stock level in final product WH	Max. stock level in temporary stock area	Max. stock level in Inputs WH
1	2538	1105	113	1216
2	2560	1168	165	1305
3	2702	1623	282	2149

Table 4: Forklifts Utilizations

Sceneries	Monthly production (pallets)	Logistic Forklifts Utilizacion	Line Forklifts Utilizacion	Inputs WH Forklifts Utilizacion
1	9321	81,77%	84,25%	64,38%
2	13673	93,70%	80,45%	69,34%
3	19267	84,80%	76,20%	69,43%

As shown in the table, variation in the work schedule of the packaging line, can strongly impact on the quantity of final product that must be shipped and on empty cans and raw materials requirements. This causes a great increase in the quantity of trucks that must arrive to unload empty cans and load final product. The variation also affects warehouses capacities, but does not affect forklifts required quantities. As there are no can line forklifts yet, three of them are recommended to satisfy production requirements without collapsing the system.
Results obtained help to determinate which is the ideal production alternative to be chosen depending on the season, having into account resources and capacities required for proper operation of the packaging line. Other operational policies can be easily simulated and enable the customer to select those policies according to his requirements.

7. CONCLUSIONS

In the present work, a discrete event simulation modeling tool is used to support decision-making in the design of internal logistics of a can packaging line. The proposed simulation model allows evaluating and defining the best strategy for minimizing costs related to the impact of introducing a new packaging line in logistic operation.

The main attraction of this tool for the client is the possibility to emulate future operation policies and analyze the behavior of a system which is currently on its design step. It also allows experimenting new plant layouts, transport systems, hardware systems, etc. with no need of investing money on their acquisition or interrupting the normal operation of other lines that will interact with the new one. It results a strong tool to perform a what-if analysis which is particularly useful in the design of new systems.

ACKNOWLEDGMENTS
This paper was partially founded by CONICET under Grant PIP-2221 and from UNL under Grant PI-81-481.

APPENDIX

A. GLOSSARY

Path (Figure 6): used to define a pathway between two node locations where the travel time is determined by the path length and a traveler's speed. Entities or vehicles can go through it. Some of its properties are speed, capacity and length.

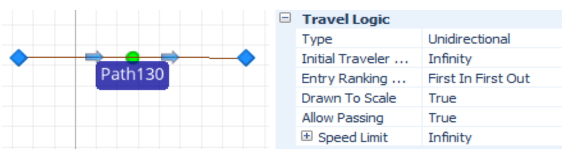

Figure 6: Path module and characteristics

Server (Figure 7): represents a processing activity in the model. Between its properties they must be set: processing time, resources needed failures, internal process and events associated.

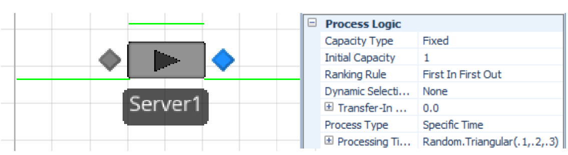

Figure 7: Server module and characteristics

Sink: represents a final point in the model where entities go to be eliminated.

Vehicle (Figure 8): transports entities from one point to another. It has assigned a pick up and drop off point. Other properties are speed, loading and unloading time and capacity.

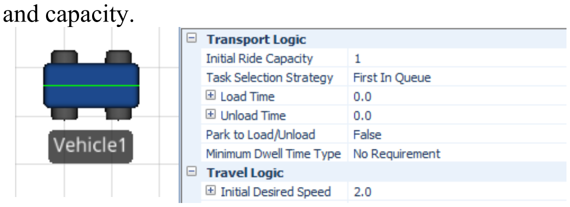

Figure 8: Vehicle module and characteristics

Workstation: represents a more complex server. It has properties such as setup time and it consider consumption and production of materials based on a BOM matrix.

Internal logic process (Figure 9): A sequence of commands that dictate the behavior of an object. It allows including inside standard modules some tasks to custom them such as seizing or releasing resources, assigning variables and firing events.(Achkar, Picech and Méndez 2015).

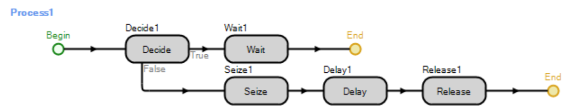

Figure 9: Path module and characteristics

REFERENCES

Achkar V.G., Picech L.S., Méndez C.A., 2015. Modeling, simulation and optimization of logistics management of a cans packaging line. Proceedings of the 27th European Modeling & Simulation Symposium, 395-402. September 2015, Italy.

Aguirre A.M., Müller E.J., Seffino S.E., Méndez C.A., 2008. Using an advanced discrete-event simulation framework to productive capacity management of a car-parts factory. Proceedings of the 20th European Modeling & Simulation Symposium, 159-168. September 2008, Italy.

Banks J., Carson J.S., Nelson B.L., Nicol D.M., 2005. Discrete-Event System Simulation. U.S.A.: Pearson Prentice Hall.

Basán N.P., Cóccola M.E., Méndez C.A., 2015. Conducting experimental design and optimization of the system configuration and operation of an innovative car rental business. Proceedings of the 27th European Modeling & Simulation Symposium, 166-171. September 2015, Italy.

Bruzzone A.G., Longo F., 2013. An Advanced Modeling & Simulation Tool for Investigating the Behavior of a Manufacturing System in the Hazelnuts Industry Sector. International Journal of Food Engineering. 9(3): 241-257.

Pedgen, C.D., 2009. An Introduction to SIMIO for Begginers. Available from: http://www.simio.com/resources/white-papers

Seila A.F., Ceric V., Tadikamalla P., 2003. Applied Simulation Modeling. USA: Brooks/Cole Thomson Learning.

Thiesing R., Watson C., Kirby J., Sturrock D., 2015. SIMIO Reference Guide, Version 8. Available from: SIMIO software support.

AUTHORS BIOGRAPHY

Victoria G. Achkar is an Industrial Engineer and PhD student at National Scientific and Technical Research Council (CONICET). Her research interests include hybrid simulation & optimization tools for logistic management of complex production and distribution processes of industrial interest.

Valentina Bär is an advanced Industrial Engineering student conducting research in optimization and simulation tools for production planning and scheduling of automated production systems.

Franco Cornú is an advanced Industrial Engineering student conducting research in optimization and simulation tools for production planning and scheduling of automated production systems.

Dr. Carlos A. Méndez is a Titular Professor of Industrial Engineering at Universidad Nacional del Litoral (UNL) in Argentina as well as a Senior Researcher of the National Scientific and Technical Research Council (CONICET) in the area of Process Systems Engineering. He has published over 200 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. His group's web page is: http://servicios.intec.santafe-conicet.gob.ar/grupos/capse/.