MODELING, SIMULATION AND OPTIMIZATION OF LOGISTICS MANAGEMENT OF A CANS PACKAGING LINE

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ABSTRACT

This paper presents the development and application of an advanced discrete event simulation model for logistics management of raw materials and final products of a cans packaging line used in an important brewery company. Advanced techniques for discrete event simulation are utilized to cover a wide range of methods and applications to emulate, advice and predict the behavior of complex real-world systems. The selected tool is SIMIO simulation software, which facilitates, through a modern 3D interface, the verification and validation of the model. Based on the proposed model, a what-if analysis is performed to determine the thresholds values of the current system and determine critical variables. The model analyzes the behavior of a future scenario which considers a significant increase in the packaging line production rate.

Keywords: Logistics, Simulation Model, Packaging Line.

1. INTRODUCTION

Modeling and Simulation (M&S) tools have become an issue of increasing importance to aid complex decision making arising in process design and operations. Recently, many real-world processes evolving over time have started to be studied by using detailed discrete event simulation models (Banks, 2004). 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 also related to M&S in food industry (Bruzzone and Longo, 2013; Callahan et al., 2005). M&S-based approaches in the food industry can be found in Husseinn et al. (2009), Reiner and Trcka (2004), Huda and Chung (2002) and Lipnizki et al. (2002).

M&S-based approach 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 (Banks, 2004; Karacal, 1998). The main advantage of M&S when studying and analyzing manufacturing and logistics systems is the possibility to take into consideration multiple aspects without introducing restrictive assumptions (Bruzzone, 2004). This is one of the principal differences between M&S and analytical approaches.

Motivated by the decision of increasing the capacity of a cans packaging line, the company under study decided evaluating the future impact of the change by using a simulation model. Major constraints to be considered are limited storage space and material handling capacity.

This work aims to represent the actual process operation in order to analyze critical variables associated to storage and material handling devices to move raw materials and final products. The goal is to evaluate alternative modes of increasing production rate without generating problems into internal logistics. Thus, we developed a simulation model to accurately reflect different scenarios to be studied. The software chosen for this work, SIMIO, is a modern tool for building and running dynamic models of systems (Simio LLC, 2010). When running the model, it is possible to see a 3D animation of the system behavior. This allows observing the operation of the proposed system before building or performing any changes. Since the simulator uses an object-oriented approach, a simpler and more organized model development of complex systems is achieved. Another work has recently used this modern tool to solve similar situations in decision-making processes (Basán et al., 2013).

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

2. METHODOLOGY

To make a model that is able to reproduce the behavior of the real system, it is necessary to collect information from multiple sources using different techniques. This took place in the company under study through: (i) in situ

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observation, (ii) interviews with staff of the company and (iii) collection of historical data.

Once obtained the desired information, it was filtered and analyzed to become input data. The input analyzer tool was used to fit arrivals data to proper statistical distributions. Among the most relevant inputs may be mentioned: packaging speed, tasks made by each forklift, operation time available for every element, warehouses and cellars capacity, arrival schedules of different truck types (empty cans, final product dispatches, other raw materials, etc.). Subsequently, this information was used in the verification and validation stages of the model.

Once the operation of the system was fully understood, a conceptual model was generated. This was used to obtain a sufficient abstraction level of the problem and to define the assumptions. Each assumption was reviewed and agreed through successive interviews with specialized personal of every sector of the company.

Finally, the model in the SIMIO software (Pedgen, 2015) was developed. 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.

The simulation model was used to: (i) represent the current operation of the system, (ii) make an analysis of critical variables of the system, evaluating its limits under current operating conditions, and (iii) propose a scenario in which, with a desired production speed, it is possible to identify necessary changes and performance variables impact.

3. INTERNAL LOGISTICS SYSTEM AND SIMULATION MODEL

The process of storing and moving raw materials and finished products includes different sectors, which simultaneously perform different tasks and depend on each other for proper operation. In this paper the sectors that are taken into account are directly related to the process of cans packaging. These sectors are: Cans packaging line, Warehouse and cellar line, Raw material storage, Main loading and unloading area, and Secondary loading and unloading area.

In order to develop the simulation model, it is first necessary to understand the operation of the actual process to clearly identify its main elements. In the system under study the following elements are identified:

- Pallets of final product (Cans and "Other")
- Pallets of different raw materials
- Objects that represent intermediate products or scrap
- Forklifts of different sectors
- Loading and unloading docks

- Warehouses and cellars
- Temporary stock areas
- Paths to connect the different sectors
- Packaging line

The model developed in SIMIO uses a factory scale plan, which can be seen in Figure 1. To start the development of the model, elements from the standard library of SIMIO are used, such as Source, Server and Sink elements. As we investigate into detail, custom elements with internal logic processes are created.

To simulate the internal logistics system, it is necessary to represent the main components of the system as mentioned above. Figure 2 shows the different views of the model developed in SIMIO.

Figure 1: 2D SIMIO Model - Layout. (1) Packaging Line, (2) Line Temporary Stock Area, (3) Warehouse and cellar belonging to line, (4) "Others" Warehouse, (5) Main Loading and Unloading Area, (6) Raw Materials Warehouse, (7) Secondary Temporary Stock Area, (8) Secondary Loading and Unloading Area

Figure 2: SIMIO 3D Model – 3D views of various sectors of the system

Elements modeled in SIMIO are listed below. The first three items represents entities that moves through the system and can be seen in Figure 3.
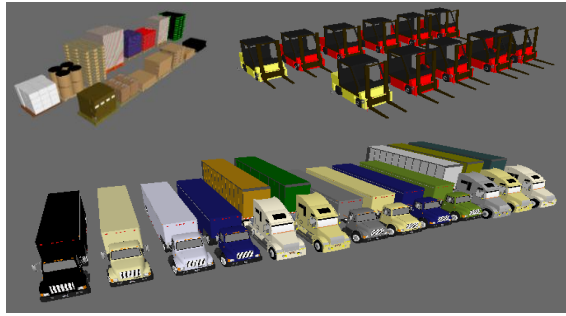
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Figure 3: SIMIO 3D Model – 3D views of pallets, forklifts and trucks

3.1. Trucks

Trucks are differentiated by function (load or unload) as well as their transporting contents. Depending on the vehicle type, it is considered an arrival following a Schedule or a statistical distribution.

In Table 1 different type of trucks and their characteristics are listed.

Table 1: Truck features

Truck	Pallets destination (sectors in Fig. 1)	Truck Arrivals
Empty Cans	Pallets unloaded in (5), stored in (3)	Weekly Schedule
Final Product	Pallets picked-up in (3), loaded in (5)	Monthly Schedule
Others Unload	Pallets unloaded in (5), stored in (4)	Exp(19.1) min
Others Load	Pallets picked-up in (4), loaded in (5)	Exp(20.6) min
Raw Materials (except empty cans)	Pallets unloaded in (8), temporary stored in (7) finally stored (6)	Monthly Schedule

3.2. Forklifts

Eleven forklifts were identified: one for the packaging line, another to the raw materials warehouse, and the remaining belonging to logistic areas. Depending on the forklift type, different speeds, loading and unloading times and carrying capacities are assigned. Unproductive times are also assigned, either by maintenance, breaks and days off. They are represented in the model with Vehicle module. Each type of forklift and their characteristics are listed in Table 2. Then, Table 3 shows every forklift visiting points (places within it moves to perform tasks) and its work schedule.

Table 2: Forklift characteristics

Forklift	Quantity	Speed	Capacity
Line	1	5 km/hr	1 pallet
Primary Logistics	8	10 km/hr	2 pallets
Secondary Logistics	1	10 km/hr	2 pallets
Warehouse	1	10 km/hr	1 pallet

Table 3: Forklift visiting points and work schedules

Forklift	Visiting points (see Fig.1)	Work Schedules (24hr days)
Line	(1) – (2)	7 days a week, 4.7 daily not operative hours
Primary Logistics	(3) – (4) – (5)	From Sunday 22h to Saturday 18hr, 1.5hr of daily work relief
Secondary Logistics	(7) – (8)	From Sunday 22h to Saturday 18hr, 1.5hr of daily work relief
Warehouse	(2) – (6) – (7)	From Monday to Friday, 1.5hr of daily work relief

3.3. Pallets of different materials

Raw material pallets, final products (cans and other materials) are represented through SIMIO entities. They are also identified entities to be dismissed due to rejection rates or secondary entities that are used to represent occupation in certain processes.

3.4. Cans Packaging Line sector

The cans packaging line works 24 hours a day. However, due to unexpected interruptions, only 80% of this time is considered productive. It has a packaging speed of 10.11 pallets/hr with its consequent consumption rate of raw materials.

For immediate supply, it has a close temporary stock area. It also has a cellar and a warehouse. While cans final products pallets are stored in the first one, empty cans pallets are stored in the second one. There is an exclusively forklift designated to this sector.

3.4.1. Packaging line

The line has a production speed in pallets/hour and every day it goes through an unproductive period of time represented by multiple causes. We also model a variable that monitors if there is an unexpected line interruption.

Consumption of raw materials in the line is modeled according to the requirements of materials by final product (BOM matrix). Every raw material in the model has a defined replenish point which, when crossed, triggers a request to bring material to the line. In addition, every pallet leaving the line requests a transfer to the final product warehouse. At most, two pallets can be accumulated in the output of the line.

Concurrently, there are secondary tasks destined to remove raw material pallets and packaging scrap, and then to pack them for its subsequent devolution.

The line forklift is in charge of feeding the line with pallets of the temporary stock area, removing pallets from the output of the line and performing secondary tasks described above.

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This line is represented in the model with Workstation, Source, Server and Sink modules, as it can be seen in Figure 3.
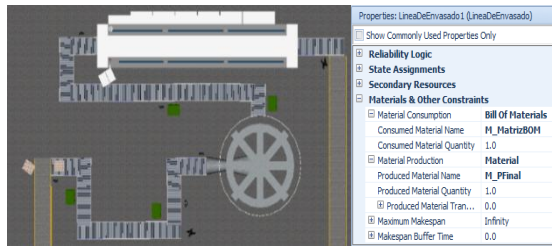

Figure 3: SIMIO 2D Model – Cans Packaging Line and some of its properties

3.4.2. Line temporary stock area

The warehouse forklift transports once a day an enough quantity of every raw material in order to satisfy a certain period of time (depending on the day of the week) and without exceeding its limited capacity. When requested, the line forklift retires pallets of each raw material to feed the line. Figure 4 shows the temporary stock area represented by a set of Servers. They store each raw material with capacity restrictions and processes that wait material requests from the line.
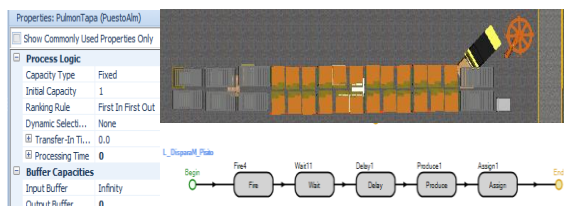

Figure 4: SIMIO 2D Model - Temporary stock area belonging to line, its properties and an internal process

3.4.3. Line warehouse and cellar

This sector is used for storing on the one hand the final product and on the other empty cans. Both sectors are modeled similarly: they receive and deliver pallets to/from different sectors. Each has an assigned capacity which may be diminished by an operational company policy.

The line forklift provisions the final product cellar from one pallet at time, and this cellar releases 26 pallets each time it is requested. Logistics forklifts remove and carry them to a given dock and perform the truckload.

Logistic forklifts provision the empty cans warehouse whenever there comes a truck and simultaneously a line forklift picks up those pallets to replenish the line.

The cellar and the wharehouse are represented in the model with Servers that have internal processes to retain the entities until they are requested and route them to where they should go. Figure 5 shows them.
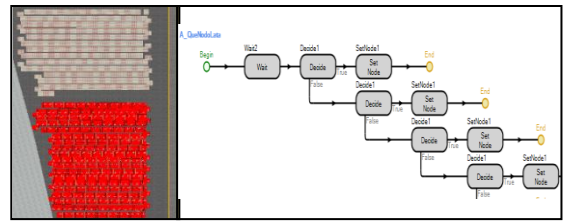

Figure 5: SIMIO 2D Model – Warehouse, cellar and an internal process

3.5. "Others" Warehouse

To approximate the use of logistic forklifts to reality, the model includes the loading and unloading of "Other" products and it would represent anything not related to the production of cans. For this, the elements Source and Server are used. The model creates these products with a certain time interval between them, so that it reaches to charge all trucks which come and load without model saturation. A Sink module is used to discard all products downloaded from the trucks that do not contain raw material for the cans packaging line. The modules have internal processes that indicate, for example, where should be directed forklifts for charging each dock. Figure 7 shows the "Other" warehouse with some internal processes assigned to it.
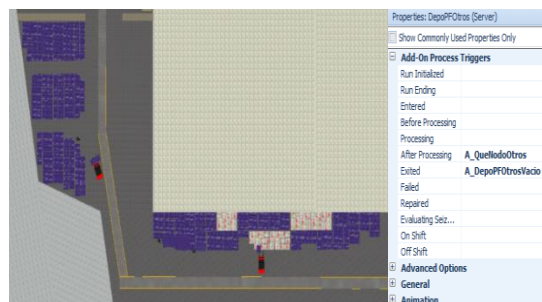

Figure 6: SIMIO 2D Model – Warehouse "Others" and its properties

3.6. Raw materials warehouse

This warehouse is shared with all packaging lines of the company. It has a defined capacity and it stores all raw materials involved in the cans line, except for empty cans pallets. In the model we consider only storage activities that are related to the line under study.

The exclusive warehouse forklift enters raw materials into the warehouse and then it distributes them to the line once a day.

The raw materials warehouse is modeled in a similar way to the empty cans one mentioned above. It has a certain capacity destined to raw materials used in the cans line, and enough quantity of them in stock in order to supply the line. In the model this is represented, as shown in Figure 7, with a server to every raw material and internal logic processes which retain them until the line request them.
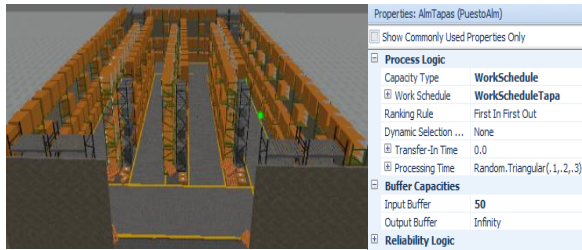
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Figure 7: 3D SIMIO Model - Raw Materials Warehouse and one of its Servers properties

3.7. Loading and unloading areas
The company has two of these areas: the main one used to load all final products and unload empty cans pallets, and the secondary one used to unload raw materials pallets.

3.7.1. Main loading and unloading area
This sector has four docks used for loading and unloading pallets from trucks arriving at the company. For proper operation each dock has a maximum of two forklifts assigned to perform such tasks. Therefore, this sector has eight logistic forklifts. In the model all loading and unloading activities of the company are represented, but those corresponding to the line under study are differentiated from others.

3.7.2. Secondary loading and unloading area
Its operation is similar to the area mentioned above, but in this case it is a single dock that only makes downloads of raw materials that, depending on the type of material, require a logistic forklift or not. While this forklift makes an unload, it locates pallets in a stock area next to the dock, and once a day, the exclusive warehouse forklift empties this area carrying pallets into de raw materials warehouse.

For both areas in the model, docks receive different types of trucks and, depending on that, perform a loading or an unloading task. If there is and unload task, a determined quantity of pallets of the material contained in the truck is created and logistic forklifts transports them until the truck is emptied. If a loading task is required, once the truck arrives to de dock, the product to load is requested from its location and the liberation of those entities is ordered, so that forklifts can pick and transport them to the truck. Through variables that monitor the loading or unloading process it is controlled the remaining quantity to load or unload. Once the truck finishes its task, there is a delay representing truck conditioning and then it leaves and liberates de dock. In the model representing the current operation of the company, distributed operations along a month are represented, corresponding to 108 unloads of empty cans pallets, 254 load of can final products pallets, 1889 unloads and 2032 loads of "Other" pallets. In SIMIO, we

represent docks with a simple Server and with many internal logic processes responsible for creating entities, monitoring with variables different restrictions to be accomplished, and destroying the truck once the task is finished. Figure 8 shows docks of the principal loading and unloading area with one of its internal processes.
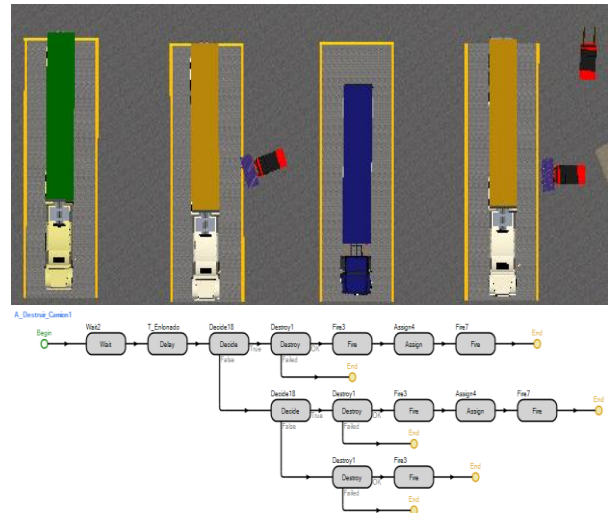

Figure 8: SIMIO 2D Model – Docks of main loading and unloading area, and internal dock process

3.8. Entries
The entries to loading and unloading areas are modeled with Source and Server modules. Source elements are responsible for creating different type of trucks following its corresponding arrival schedules. Figure 9 shows the representation of the entrance to the main loading and unloading area and an internal process.

Figure 9: SIMIO 3D Model – Entry and internal logic process
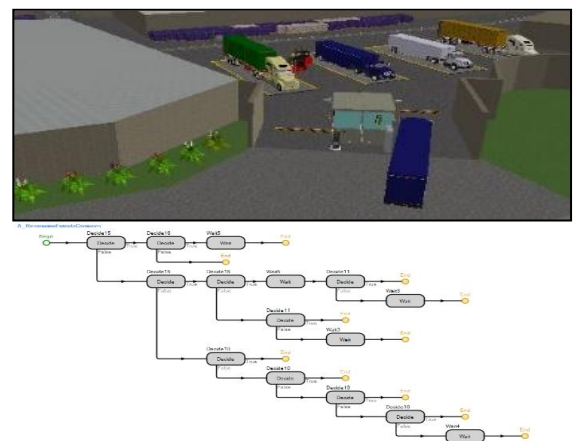
There are defined restrictions that prevent the entry of trucks in the following situations: (i) if it is a day that docks do not operate, (ii) if it there is not an available dock, (iii) if there is a certain amount of

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trucks of the same type within the loading and unloading area simultaneously (the amount depends on the type) or (iv) if there is not availability of final product. We also assign to the entries a delay representing documentaries issues.

4. VERIFICATION AND VALIDATION

Verification is concerned with determining if the conceptual model with its specifications and assumptions were correctly traduced in computerized representation (Law and Kelton, 2007). To carry on, we perform a detailed analysis of different output variables, within the most relevant: (i) quantity of final product packed, (ii) utilization of every forklift, and (iii) usage of docks. We compare these values with calculations based on assumptions of the conceptual model. In this way, concordance is verified and the model is adjusted in case of finding discrepancies.

Then, validation is carried out, which is concerned with determining how closely the simulation model represents the actual system (Law and Kelton, 2007), to the particular objectives under study. For this process we make an iterative comparison between the values obtained from the computer model and the information provided by the company about the time period represented (critical production month) and through subsequent interviews.

The main values compared are (i) daily occupation of store and warehouse line, (ii) monthly production, (iii) monthly downtime, (iv) number of trucks arriving per day of each type and (v) utilization rate of forklifts. The necessary settings and changes in the model are made to ensure that these values are similar to the records of the company and, in addition, have been accepted by the staff of the company involved with the development of the model.

5. DEFINITION OF SCENARIOS AND EXPERIMENTATION

Output analysis is the examination of data generated by a simulation. It purpose is either to predict the performance of a system of to compare the performance of two or more alternative system designs (Banks 2004). In this step we generate all data needed and we make an analysis of the impact that decision variables have on response variables through the design and simulation of different scenarios.

For the case under study, we define different scenarios increasing the line speed until achieving the desired one (25.28 pallets/hr). As a consequence of changing the design, we decide to add an extra forklift to the line and to increase the quantity of arrives of trucks associated to the cans line.

We define the following response variables: (i) monthly production, (ii) the use of the line forklift, (iii) the use of logistic forklifts dedicated to primary load and unload area, (iv) the use of the docks of that area, and (v) increasing of trucks quantity arriving to the main area.

For the definition of different scenarios analyzed increasing packaging speed, we make some modifications to the current operation policies of the company. These are mainly related to the number of trucks that daily arrive to load cans final product and unload empty cans pallets. These new policies redefine: (i) the number of daily arrivals of each type of truck throughout the month and (ii) the number of arrivals calculated in such a way that line warehouse and cellar have a stable occupation in the long term.

The results of the simulation are shown in Table 3.

Table 3: Summary of results

Number of line forklifts	% increase in packaging speed	Performance system variables					
		Monthly production (pallets)	Line forklift usage	Logistic forklifts usage	Docks usage	% increase in empty cans trucks	% increase in final products trucks
1	-	6037	76%	49,5%	58%	0%	0%
	+10%	6635	83,3%	49,7%	58,5%	0%	+0,4%
	+20%	7239	91%	50,1%	59,1%	0%	+11%
	+31%	7949	99,9%	51,0%	60,1%	+7,4%	+21,7%
2	+50%	9048	57,1%	52,1%	61,41%	+25%	+28,2%
	+90%	10253	72,8%	54,3%	63,98%	+53,7%	+74,4%
	+130%	10253	89,2%	56,7%	66,63%	+88%	+110,6%
	+150%	15082	96%	60%	69,97%	+104%	+132%

As we can see, the line speed variation impacts heavily on the use of line forklift. That happens because speed directly affects the frequency of feeding the line and removing final product from it.

The use of logistic forklifts and docks varies in a lower magnitude. This is because the number of trucks related to can's transportation does not significantly increase the total number of trucks.

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In the first scenarios there is not a significant increase in the number of trucks because in current situation the required amount is exceeded (we can see in the model that occupation of warehouse increase and of cellar decrease). Moreover, this augmentation is only related to two specific types of trucks (those related to cans production) representing a smaller percentage of the total arrivals in the model. Consequently, it does not significantly affect forklifts and docks usage.

We note that a single line forklift can increase production up to 31% without saturating the system. Subsequent increases are only feasible if we add another line forklift. With two forklifts assigned to the line, the model confirms the possibility to operate in the future at the desired speed by the company (25.28 pallets / h).

6. DISCUSSION

In this work we presented the development of an advanced simulation model to assist the decision making process in materials and final products logistic management related to a cans packaging line of an important brewing company.

We chose the simulation software SIMIO, resulting a flexible, robust and modern discrete event simulation based tool. The proposed model had allowed the company to predict the effect of a future expansion of the production capacity, mainly related to the available storing capacity and handling resources.

The developed work allowed to anticipate and to quantify the impact of future planned changes in different critical variables of current system, finding its limit values. The results obtained were very useful to enable the company to make decisions in advance without altering the current system and avoiding unnecessary costs.

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APPENDIX
A. GLOSSARY

Path: 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.

Internal logic process: 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.

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

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

Vehicle: 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.

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.

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