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APPLYING A DYNAMIC SIMULATION MODEL RECONFIGURATION LOGIC TO ERP SYSTEM

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Abstract. *This study shows the contribution of Discrete Event Simulation (DES) for improvement of statics production scheduling process in the environment of dynamic demand. Using simulation software, named Tecnomatix Plant Simulation 13[®] by Siemens, it was possible to structure a digital factory model, define and validate the operating logic of this model, which enables the automatic reconfiguration of production planning. The virtual model represents the operations of the eyeglass industry from customer requests to collect final product. In this case, the purpose is to dynamize most of the production planning process, then it will execute automatically in a virtual system and guide the physical operation. The result is a virtual model that allows the integration between production management systems with simulation tools, besides increasing productivity, reducing waste and improving the labor productivity.*

Keywords: *Discrete Event Simulation, Modelling, Production Planning, Digitalization.*

1. INTRODUCTION

The dynamism of the globalized consumer market requires increased agility of production systems in response to changes and improvements in the manufacturing process (Brown *et al.*, 2015). In this context, some computational tools and applications are being more frequently used to support changes in the real manufacturing process because they guide an execution previously validated in a virtual environment.

The Discrete Event Simulation (DES) is highlighted among computational tools because it also allows the reproduction of a real system in a virtual environment. The computational modelling is based on data collection, model logic and results validation (Law and Kelton, 1991). Considering these aspects, the simulation model becomes a tool applicable to assessment of changes in production systems without necessity of intervention in the real environment (Pidd, 2006).

A real DES utilization was described by Chemweno *et al.* (2014) in a case study that aimed to improve the service in an university hospital focusing on the analysis of waiting time reduction for patients. In this study, the authors analyzed five simulation scenarios based on service variables, such as queue waiting time and number of patients (Chemweno *et al.* 2014). Besides that, the authors highlighted the use of DES to evaluate the impact of operational changes as the implementation of alternative policies on the waiting time.

A similar application was developed by Shi *et al.* (2014), they used DES to simulate three scenarios of a clinic with complex characteristics. However, the goal was to estimate the occupancy rates of attendants and nurses without compromising service time and waiting time for the system users (Zheng *et al.*, 2018).

In addition to the case studies found in the scientific literature, the importance of DES is reinforced by its application in the context of Industry 4.0 as part of the digitization and development of Smart Factories (Lee *et al.*, 2015; Turner *et al.*, 2016).

However, it is noteworthy that for the previously mentioned studies, the simulation model is basically static although it represents a dynamic production or service systems environment. In other words, if the system has some changes the simulation model becomes outdated, making the decision-making process inaccurate (Robinson *et al.*, 2014). This fact occurs because the simulation model is programmed to follow a specific and non-variable routine, but when this routine is changed, it is also necessary to update the model parameters in order to represent the real environment again (Robinson *et al.*, 2014).

An example of this scenario is the difficulty in developing a simulation model that is reconfigured according to the variation of customer demand. Thus, the model executes actions only after receiving a list from customers demand, allowing decision makers to always have an updated simulation model.

Therefore, the Core Manufacturing Simulation Data (CMSD) was developed for execution of dynamic simulation models, i.e. the operation is to recognize changes in the real environment and take them to the virtual environment

(Furnier, 2011; Johansson *et al.*, 2007; Lee *et al.*, 2007). The CMSD is a programmed code that receives data from the production system and feeds the simulation model in real time. Generally, the collected information includes process lead time, setup time, production scheduling, among other data that can come from manufacturing systems, such as MES (Manufacturing Execution System) and RFID (Radio-Frequency Identification), and from company information management systems, such as ERP (Enterprise Resource Planning).

The application of CMSD is already consolidated but its complexity of operationalization may make difficult the adoption of this tool by some companies. In cases of simulation of complex manufacturing systems, other tools are used, for example hybrid modelling (Farsi *et al.*, 2019).

In this context, this study aims to develop a dynamic simulation model that reconfigures itself through customer demand changes. Therefore, it will be possible to link the simulation model to the requirements and demands of the customers from ERP, allowing the reconfiguration of the simulation model even after its validation.

As a result, the simulation model becomes more flexible compared with other models that do not use this logic. Thus, the simulation model will be able to reprogram the distribution and manufacturing routes of parts according to the ERP data. However, machine operating data will remain static because the logic developed does not still integrate with MES or RFID.

2. DIGITALIZATION ON INDUSTRY 4.0

Since the advent of the 1st Industrial Revolution, great advances have been made in the industrial area due to the need to increase productivity and reduce costs. The emergent Industrial Revolution, also known as the 4th Industrial Revolution or Industry 4.0, aims not only to improve production processes, but also the other areas that make up and support the industry processes (Schuh *et al.*, 2014).

The concept of Industry 4.0 emerged in Germany in 2011 because of policies based on high technology utilization for manufacturing processes (Roblek *et al.*, 2016). Its emergence was not only due to the need for greater integration of production systems, but also to ensure competitiveness in the current scenario of high changes and availability of technological and information resources that enable these advances.

Industry 4.0 relies on advances in Information and Communication Technologies (ICT), such as reducing the size of hardware, increasing data-processing capacity and connectivity among devices over the communication network.

Manufacturing concepts are being revolutionized because of these technologies, especially in the informational area. The main objective in using these concepts is to achieve greater automation and manufacturing digitization, integrating information throughout the entire supply chain.

Concepts such as artificial intelligence, big data and connectivity are parts of this revolution and they represent improvements in production automation and digitalization, system connection and data exchange among supply chain manufacturing sites (Roblek *et al.*, 2016).

Fundamentally, this revolution will create Intelligent Factories, where there are horizontal and vertical integration between human and machines simultaneously and dynamically, operating together with objects and information which make up the intelligent production system (Prause and Weigand, 2016).

One of the main factors that contributed to the development of the Smart Factories in the fourth industrial revolution was the increased capacity in the digitization of factories and processes (Efendioglu *et al.*, 2017).

Digitalization began in the 1970s with the introduction of controls and microprocessors in factories in conjunction with Information Technology (IT) development. Today, digitization is broader and encompasses operations, product development beyond relationship with the supply chain and customers. One of the challenges of digitization is to cover the entire supply chain (Isaksson *et al.*, 2018).

Basically, the digitalization in the production system consists of creating a computer model, that is a twin of the physical environment. This computational environment will use to simulate and optimize conditions without intervention in the real environment, allowing the extrapolation of the experiments avoiding any consequences for the real production system.

For this, the digital transformation must be based on four pillars: ability to collect, manage and analyze digital data; ability to work autonomously and in an organized way; connectivity and synchronization with the supply chain; and digital access to customers providing more transparency and new products (Belderok *et al.*, 2016; Armengaud *et al.*, 2017; Thoben *et al.*, 2017).

Due to the complexity of the digital factories, it is necessary to build intelligent physical environments, combining physical and cybernetics technologies (Chen *et al.*, 2017; Schluse *et al.*, 2018). Another important point for the suitable functioning of the digital factory is the good architecture in mining and data storage in the Big Data scope (Javaid *et al.*, 2017). This data collection must be performed in real time by tools such as MES and RFID because they are directly connected to the production system (Thoben *et al.*, 2017; Javaid *et al.*, 2017; Leng *et al.*, 2019). Experimentally, the concepts of real time digitalization and information exchange were applied by (Vachálek *et al.*, 2017).

2.1 Discrete event simulation (DES)

Discrete Event Simulation (DES) allows analysis of complex and stochastic process chains in manufacturing systems on an arbitrary level of abstraction, it is applied to analyze problems that involves areas of healthcare, marketing, supply chain, economy, military, ecology, among others (Negahban and Smith, 2014; Stoldt *et al.*, 2016). In the discrete event models, state variables remain static for period time and they only change in the case of event occurrence.

The DES software's are being increasingly used in operational applications, because of the improvement of computational tools and reduction of time to build and run simulation models (Haraszko and Németh, 2015). Haraszko and Németh (2015) list some commercial DES software's, among them: Anylogic by Anylogic, Arena by Rockwell Automation, FlexSim by FlexSim Software Products, Plant simulation by Siemens, and Witness by Lanner.

Negahban and Smith (2014) emphasize that in manufacturing operations planning and scheduling, the DES is not applied only to production planning, it also is used to support the decision makers in the long-term production planning and short-term scheduling (Negahban and Smith, 2014).

However, for DES conduction is necessary to organize the case studied in a sequence of steps which will ensure the quality and efficiency of the virtual model developed. In summary, the steps are: Problem formulation, Model conceptualization, Data collection, Model building, Verification and validation, Analysis, Documentation and Implementation (Di Gironimo *et al.*, 2015). Thus, the result is a simulation model that searches the better scenario through system optimization.

Moreover, there are other computational tools used in the industry to support production management, which can be linked with DES, for example ERP (Enterprise Resource Planning) systems (Höppe *et al.*, 2016). This kind of study makes the industry environment more flexible in cases of demand fluctuations because the data are available in real time and the systems of simulation and management are increasingly connected.

3. PRODUCTION SCHEDULING

Production scheduling directly affects the industrial competitiveness because of the delivery of products that influences customer satisfaction, service level as well as production costs. Indeed, the scheduling of production has dynamic requirements and significant structural complexity, which are challenges in the industrial operation (Frazzon *et al.*, 2016).

The production scheduling is a key activity responsible for decisions of production in short and long term. Most of the time, these decisions are made manually by a planner who must define demand data (quantity, products type, production resources, time to delivery) in the information system. The scheduling problems arise when there is an operational condition of manufacture a specific product in a specific resource that has a sequence of tasks, this kind of situation comes up in any industry area (Harjunkoski *et al.*, 2014).

In this context, the use of DES allows real time verification of data production, definition of production sequence, verification of production orders, specifications and features of production systems, furthermore the simulation results can provide an analysis of production systems constraints in future scenarios, which facilitates production planning activities (De Couchelle *et al.*, 2019; Güçdemir and Selim, 2018; Krenczyk *et al.*, 2016).

4. DEVELOPMENT OF CONCEPTUAL MODEL

According to the objective of developing a dynamic simulation model and reconfiguring it based on demand changes, this study focuses on developing a conceptual model that can be applied in cases with similar scenarios.

Thus, it is important to understand the logic used for the operation routines of the most trivial simulation models. Figure 1 shows the general operating logic view used for the evaluation of production systems. In this case, the logic includes:

- Source List: In all simulation software there is a tool responsible for managing the input of entities in the simulation environment, these entities can be pieces, people, raw material, documents or container;
- Buffers and Deliveries: While entities are in the simulation environment, they may be in stock, in motion, or in transformation. In cases of entities in stock or movement there are specific tools that are programmed to manage respective parameters;
- Parts Manufacturing and Assembly Parts: Every simulation model has tools that symbolize machines or service stations that will transform or combine entities. These tools inform all necessary parameters for the transformation of the entities besides the definition of the equipment operation logic;
- Shipping Department: After the entity transformation, the last step is to remove it from the simulation environment, symbolically it would be the delivery to the customer. This tool is responsible for collecting data regarding delivery and efficiency of the analyzed production system independent of the simulation software used.

For the simulation model to work in a synchronized way, the elements that make up the model must allow an exchange of information, creating a dependence on the model's variables.

Follow some examples of relationships listed in Figure 1, noting that they are all common in several simulation models used in the representation of production systems:

1 – This first example is about the relationship between the tool that manages the input of the parts (raw material) in the simulation environment with the stock of these parts. Assuming there are different types of parts entering in the simulation environment at different times, it is fundamental that the stock has enough capacity to receive the parts and conditions to separate them according to their characteristics. If the buffer is scaled without being synchronized with the source list, at some moment the parts or raw materials will not input in the system, giving raise failures in the simulation;

2 and 3 – In examples two and three, the elements leave the stock and feed the machines responsible for the transformation of the material or the assembly of parts. In these cases, the machines operation depends on the information from the stocks or the previous stages of the process, because the machines need to identify which parts will be produced immediately. This is essential for the machine to change its operating parameters if it is necessary. Another relevant factor in this example is the necessity to define the parts distribution parameters if there is more than one machine option. However, some models of simulation may consider there is a failure of parts, which would lead to a lack of parts in the next stage of the process, causing simulation fail;

4 – The last example shows the importance of synchronization between the product stock and the transport responsible for the collection. If the buffer has different quantity or types of parts from those requested, the transport will not be able to execute this action.

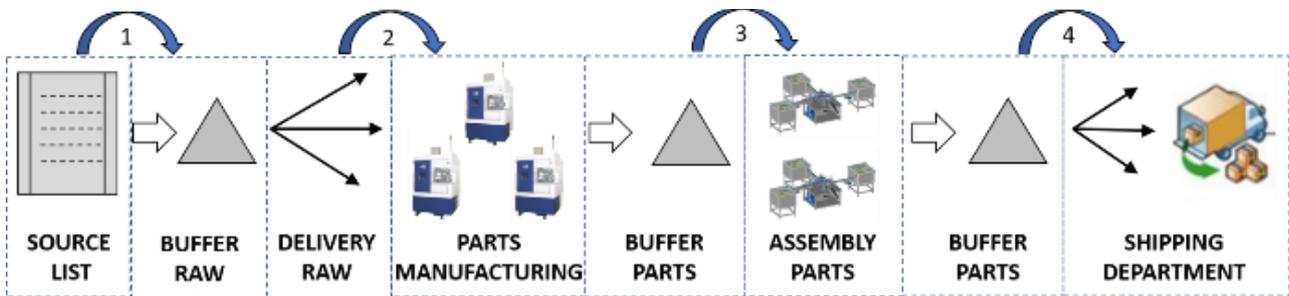


Figure 1. Example of a modelling logic in a production environment.

In the construction of a simulation model, it is important to consider the examples previously explained in Figure 1. In this case, the model will work correctly, however, it will not allow changes in synchronism parameters of the simulation model, such as size of batch and parts input sequence in the simulation environment.

In this sense, the reprogramming logic developed in this study allows that the parameters of Production Batch Size and Part Input Sequence can be changed in the simulation environment based on ERP data without the simulation model loses its operation rule. Figure 2 represents the logic developed to achieve the objective of this study.

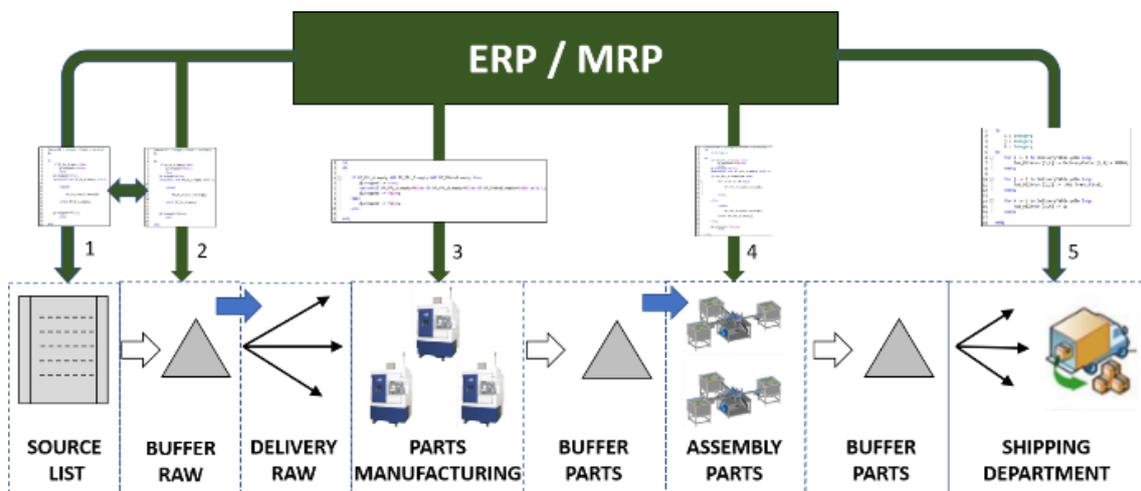


Figure 2. Example of integration between the ERP and the simulation model.

Figure 2 shows that some codes were developed with the objective to link the information from the ERP to the simulation model, allowing that some static parameters can be reprogrammed according to the changes in the ERP.

Initially, the relationship between the ERP and the List that manages the input of entities in the simulation model was created, automatically allowing adaptation of the simulation model when new information is inserted into the ERP.

For the input of parts varies according to ERP data without failure of the simulation logic, the buffers need to be reprogrammed agreement to the source list data. For this condition, it is essential developing a programming that transforms the total capacity of the pieces in the buffer into the variable, besides the logic of these pieces' distribution. This same logic is used in all buffers of the simulation model.

In the areas, parts manufacturing and assembly parts, the machines are responsible for the transformation and assembly of parts. In order for machines have capacity to identify the part to be processed or assembled, a code must identify an entity variable and reconfigure machine operating parameters, such as: Processing Time, Setup Time, Assembly Logic, Guide Inputs.

Finally, a code that relates the data of the ERP to the parameters used by the transport in the shipping department was developed. Then, the parts to be collected at the end of the assembly process vary according to the customer's needs, in this way, the parts to be collected will be ordered in the buffers to avoid a logic error that would cause the transportation stop beyond the accumulation of parts in the buffers and in the previous steps of the process.

5. APPLICATION OF CONCEPTUAL MODEL

The computational model used in this case study simulates a situation in which the production of an eyewear factory has to be planned according to the customer's order list. The eyeglass factory operates from Monday to Friday in two shifts (6:00 am to 2:00 pm and 2:00 pm to 10:00 pm) and produces three different types of glasses, each with their respective frames, stems and lenses. Setup, transport and process parameters were not taken into account, as they are not the objective of this work.

The Simulated Factory Layout is divided into two parts. On the left side, parts are provided and stored so that they can be picked up by transport. After being collected, they are taken to the right side of the track, where they will be unloaded, stored and assembled. After assembly, the final products are again stored, where they await the milk run, which will collect the parts produced at the end of the shift. Figure 3 presents the model logic.

5.1 Model Logic

The model logic developed in Tecnomatix Plant Simulation 13[®] software starts in the production planning activity. The production planning carries out from a dynamic orders list filled automatically according to the customer's requests inserted into the ERP. Therefore, in order to the system completely works and accomplishes the daily production, it is necessary to link the table data to the order list. After this, other steps automatically will run in the virtual system. Figure 3 represents an overview of the entire production sequencing of the created model.

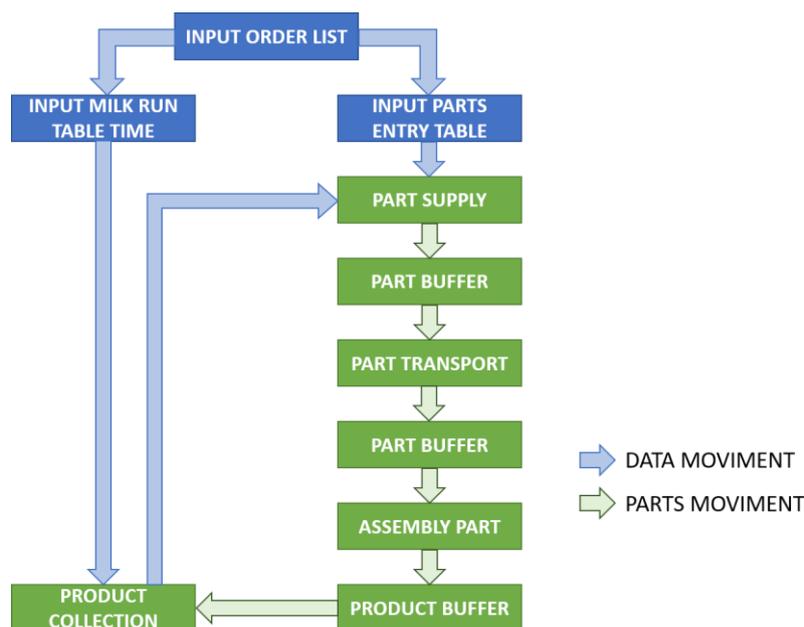


Figure 3. Model logic for the eyewear factory simulation.

In the next step after completing the requests list, two tables are automatically fed through programming methods created, including data of milk run schedule for collection and input parts table. This allows the times of milk run matching the times of order list. In addition, it is possible that parts input can be configured according to the demand, avoiding overproduction.

All the supplied parts are stored in buffers, where they are waiting for the collection by an internal transport, which works in an automated way. Transport only moves when buffers have parts to collect. Thus, parts are collected by transport and then unloaded into other buffers where it is separated by their characteristics. Both the transportation movement and the collection of parts are controlled by specific programming methods.

The parts are stored in the buffers for waiting the assembly process. After the end products assembly, they are stored in new buffers, where they wait for the collection by the milk run, which occurs at the final of the shift. The collection process is also controlled by specific programming methods for the process.

5.2 Initial Demand List

The initial step for the operation of the simulation model is to feed the customer demand data, this information is linked to the ERP and automatically filled. Figure 4 shows the orders demand information.

	time 1	integer 2	integer 3	integer 4
string	Production start	Glasses A	Glasses B	Glasses C
1	6:00:00.0000	500	250	400
2	14:00:00.0000	300	400	200
3	1:06:00:00.0000	400	500	600
4	1:14:00:00.0000	800	600	300
5	2:06:00:00.0000	500	600	250
6	2:14:00:00.0000	150	300	400
7	3:06:00:00.0000	250	350	500
8	3:14:00:00.0000	200	100	250
9	4:06:00:00.0000	300	250	600
10	4:14:00:00.0000	450	400	350

Figure 4. Order demand list.

In the first column - Production start, there are the start times of each shift that you want to plan the production. In this case, five days were simulated. The factory works in two shifts, the first is from 6 a.m. to 2 p.m. and the second starting at 2 p.m. and ending at 10 p.m. The shift schedule can be changed and the number of days to be planned is unlimited. In columns 2, 3 and 4 are inserted the products demand to be produced and each model.

5.3 Parts Supply and Storage

A programming method that feeds the parts input table from the data of the order demand list has been developed.

For this study, the quantity of frames parts should be equal to the respective quantity of glasses, while the quantity of stems and lenses should be twice their respective products assembled. Figure 5 shows the code of the method that feeds the stems input table of glasses - type A through the orders table.

```

1:  is
2:    i : integer;
3:    j : integer;
4:    k : integer;
5:
6:  do
7:    for i := 1 to OrderList.ydim loop
8:      Tab_Entr_HPL_A [1,i] := OrderList [1,i]
9:    next;
10:   for j := 1 to OrderList.ydim loop
11:     Tab_Entr_HPL_A [2,j] := .MUs.Haste_P1_A;
12:   next;
13:   for k := 1 to DeliveryTable.ydim loop
14:     Tab_Entr_HPL_A [3,k] := OrderList [2,k]*2;
15:   next;
16: end;
17:
18:

```

Figure 5. Description of code for stem input.

In this method a loop is used, starting at 1 shift and finishing at the number of shifts that are having their productions planned, in order to fill each column of the table. So, in the first loop, the first column is filled by the production start times, where the parts must be provided. The second loop fills the second column with the type of part

to be supplied, while the third loop fills the third column with the quantity of parts. Similar methods were created to feed the tables of each type of parts.

With information of the tables completed, the Source tool (responsible for entering parts in the simulation model) can supply parts according to the exact quantity that be produced. A Source tool is used for each type of part and its operation is controlled by the respective input tables. The supplied parts are stored in buffers, where the collection is expected to be carried out by a transport.

5.4 Parts Transportation

After the parts are stored in the buffers, automated internal transport is responsible for collecting and carrying them to the assembly area. This transport has the capacity of 300 pieces, which is divided into a maximum of 20 pieces of each frame and 40 pieces of each stem and lens. Nine sensors are installed in the lane and they are responsible for parts in the stands. Figure 6 – Section A shows an example of the method used for loading stems of glasses - type A.

Based on the code description, the first conditional expression (if) ensures that the transport moves forward if the buffer is empty and it stops, besides ensuring that all parts are collected. The second expression ensures that the transport will be loaded until 40 pieces of capacity with the corresponding type, or in cases that there are no more parts to be loaded. Similar methods were created for each sensor.

```

1 (SensorID : integer; Front : boolean)
2 is
3   i:integer;
4
5 do
6   if BF_FPL_A.empty then
7     @.stopped:=false;
8   else
9     @.stopped:=true;
10    waituntil not BF_FPL_A.empty prio 1;
11
12   if BF_FPL_A.nummu>20 then
13     for i:=1 to 20 loop
14       BF_FPL_A.mu(1).move(@);
15     next;
16
17   else
18     repeat
19       BF_FPL_A.mu(1).move(@);
20     until BF_FPL_A.empty;
21   end;
22
23   @.stopped:=false;
24   end;
25 end;
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To executing the collection, three load sensors were also created. Thus, their method of programming glasses - type A can be observed in Figure 7. This consists of a conditional expression that consider the transport must proceed if the corresponding buffer is empty, otherwise it must be loaded until the buffer will be completely empty.

The methods to feed the parts input table and the milk run time table depend of INIT to function correctly (Figure 7-A). Therefore, they fill the tables with the information according to the orders list (Figure 7-B). The other methods of this system are controlled by sensors and they are rotated when the front of the transport moves along the sensor (Figure 7-C).

5.6 Model Logic Validation

After elaborating the logic and developing of the model, it was necessary to validate it. For this, the model was triggered and its behavior was verified. Firstly, it was verified that the feeding methods of the milk run input tables and the milk run times were filled correctly. Even if the demand changed in ERP, the tables were filled with the values updated, ensuring that the programming logic was maintained after the changes, which can be observed in Figure 8.

String	Time 1 Production Start	Integer 2 Glasses A	Integer 3 Glasses B	Integer 4 Glasses C
1	6:00:00:0000	500	250	400
2	14:00:00:0000	300	400	200
3	1:06:00:00:0000	400	500	600
4	1:14:00:00:0000	800	600	300
5	2:06:00:00:0000	500	600	250
6	2:14:00:00:0000	150	300	400
7	3:06:00:00:0000	250	350	500
8	3:14:00:00:0000	200	100	250
9	4:06:00:00:0000	300	250	600
10	4:14:00:00:0000	450	400	350

Data By ERP

String	Time 1 Delivery Time	Object 2 MU	Integer 3 Number
1	6:00:00:0000	*.Mus.Lente_B	500
2	14:00:00:0000	*.Mus.Lente_B	800
3	1:06:00:00:0000	*.Mus.Lente_B	1000
4	1:14:00:00:0000	*.Mus.Lente_B	1200
5	2:06:00:00:0000	*.Mus.Lente_B	1200
6	2:14:00:00:0000	*.Mus.Lente_B	600
7	3:06:00:00:0000	*.Mus.Lente_B	700
8	3:14:00:00:0000	*.Mus.Lente_B	200
9	4:06:00:00:0000	*.Mus.Lente_B	500
10	4:14:00:00:0000	*.Mus.Lente_B	800

Number of Parts Enter

String	Time 1 Delivery Time	Object 2 MU	Integer 3 Number
1	6:00:00:0000	*.Mus.Trans_final	1
2	14:00:00:0000	*.Mus.Trans_final	1
3	1:06:00:00:0000	*.Mus.Trans_final	1
4	1:14:00:00:0000	*.Mus.Trans_final	1
5	2:06:00:00:0000	*.Mus.Trans_final	1
6	2:14:00:00:0000	*.Mus.Trans_final	1
7	3:06:00:00:0000	*.Mus.Trans_final	1
8	3:14:00:00:0000	*.Mus.Trans_final	1
9	4:06:00:00:0000	*.Mus.Trans_final	1
10	4:14:00:00:0000	*.Mus.Trans_final	1

Time and Products drain

Figure 8. Data entered automatically.

Subsequently, the transport of parts was verified according these analyzed conditions:

- If the transport collects parts from all buffers;
- If the parts were discharged into the correct buffers;
- If the transport went ahead if any buffer were empty;
- If the transport stopped moving if all the buffers were empty;
- If the transport was moving again at the beginning of the next shift.

All these points were observed and they behaved as expected. Figure 9 shows the transport stopped at the beginning of the track waiting for parts refill.

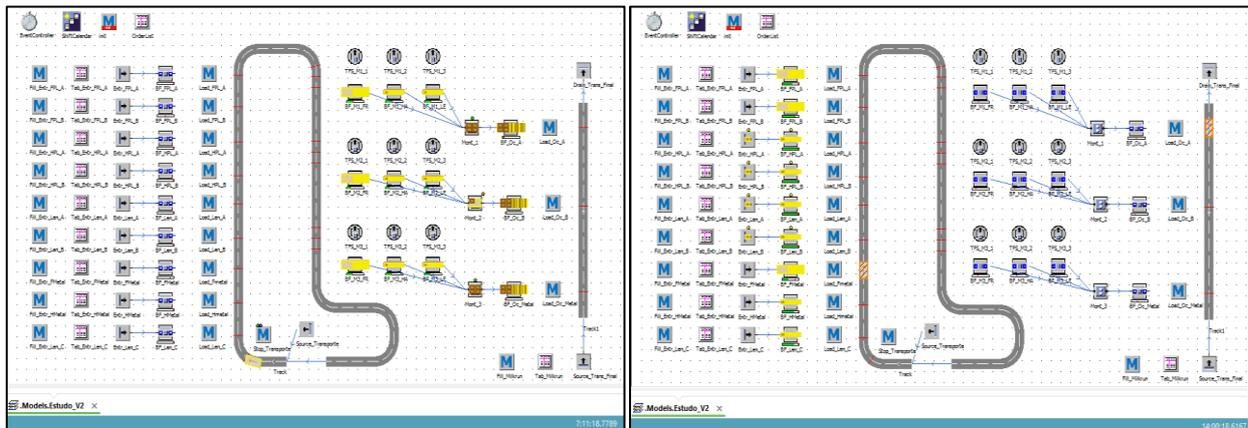


Figure 9. Simulation model at the beginning of the track.

Finally, the milk run collection system was validated. For this, two mains aspects were considered:

- If the starting time of the milk run followed the table scheduling;
- If the milk run advanced only after it completely emptying the buffers.

Both points were evaluated and behaved correctly. Figure 9 shows the milk run leaving the runway after collecting all the planned demand.

6. CONCLUSION

Based on tests of this application, we observed that the simulation model started to automatically reconfigure after changes in the production demand according to developed programming logic. The described example was based on real data from a spectacle factory in which there is a wide variety of products where it is possible to apply Discrete Event Simulation as a decision support tool through Tecnomatix Plant Simulation 13[®] Software.

One of the problems observed by the manufacturing management team was whenever a simulation model was developed, it becomes obsolete when there were changes in the production demand. This fact occurs because the parts are not produced in standard quantities, therefore all the logic developed for moving the parts in the simulation environment stops to function after the changes. In these cases, all decisions were made based on past demands data.

In this scenario, a reconfiguration logic was developed allowing that the model works regardless of the quantity of parts in each lot and of the variety of products. This was possible because the data used for the configuration of the simulation model operating parameters are based on the ERP data, becoming the simulation model more dynamic.

In this research, as suggestion for future studies is suggested the develop of a logic that allows the system to recognize the possibility of not meeting the demand, avoiding delivery delays. Thus, it is possible adapt the production lines to assembly different products previously designated. In this way, it also would be possible to make an optimization study that aims to reduce setup and production times, further increasing industry productivity.

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