- Production unit, is a package that enters the production line and is transferred from the first activity to the completion of all the activities.
- Unit per package, is the number of garments that make up the package.
- Machine, is the asset used by the sewing operator to make the pieces that make up a garment. These machines (lock stitch, overlock, coverstitch, etc.) are distributed in the production line consecutively and sequentially for the operating activities.
- Demand, is the quantity requested by customers.

The following data were taken into consideration for the development of this research:

General data:

Operation time: 8 hour/day, is the available operating time in which the production line must meet customer demand.

Demand: 600 unit/day, is the requirement of units (garments) to be delivered to the customer per day.

Unit / package: 16 unit/package, is the number of units in a package.

Production unit: 1 package, also called production batch. It enters the production line by package, starting from the first activity to the end of the last activity. The package is only broken when all the processing activities are completed.

And the following Table 1 shows specific data per activity:

Description	u.m.	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5
Tstd (hr/paq)	(Hour*machine /unit)	0.0250	0.0225	0.0417	0.0392	0.0233
Machine #	Machine	1	1	2	2	1
Setup time #	Hour/machine	0.25	0.333	0.417	0.3	0.383

I. *System Dynamics*

The field of application of System Dynamics (SD) as a tool in the construction of management models is widely used in strategic analysis to evaluate the impact of manufacturing processes [27, 28, 29], and is carried out through causal diagrams and flowcharts of complex systems, where their temporal behavior is analyzed and modeled.

The identification of the variables that make up a certain system and their cause-effect relationship allows the decision-maker to evaluate the hypothesis and quantitatively determine its impact in a preventive manner in order to modify or optimize it according to the needs. [30, 31].

The causal diagrams and flowcharts were constructed by using the Vensim PLE plus language [32].

J. *Causal Diagram*

System Dynamics plays an important role in understanding problems and their root causes to determine consequences or alternative courses of action, and to test alternatives under different scenarios. Causality starts from the fact that every type of event originates in a cause, origin or principle.

A =========➔ B

And for an event A to be the cause of an event B the following must be fulfilled:

- That A happens before B
- Whenever A happens, B happens
- That A and B are close in space and time.

The scenario model or causal diagram in Figure 11 shows the key elements of the system and the relationships between them.

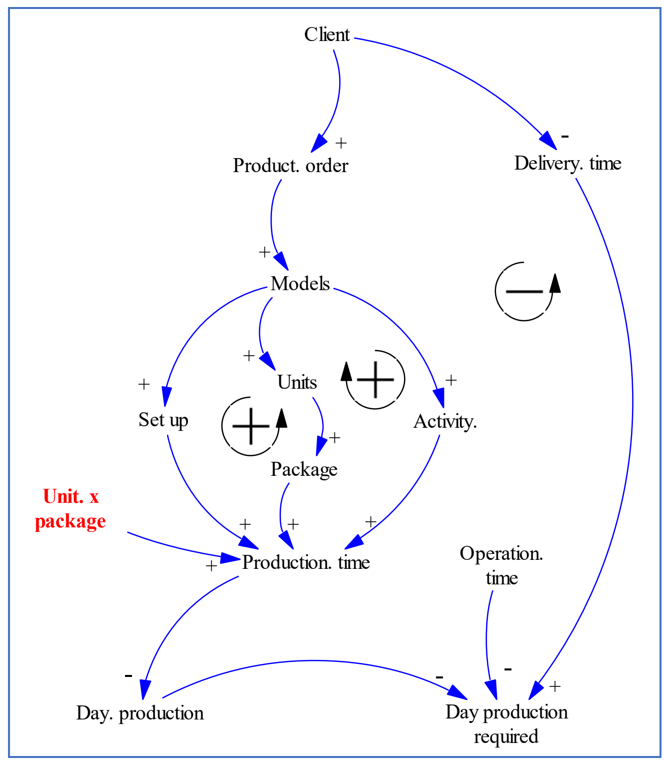

Figure 11: Causal Diagram

- The higher the number of customers, the larger the order of varied products that are required in the shortest possible time.
- The greater the variety of products, the greater the variety of models of these products.
- As the variety of models increases, the number of units and the number of activities increases, which directly affects the increase in production times.
- The greater the number of units or pieces contained in a production unit or package, the longer the execution time of the activity and the longer the production time of the line.
- The amount of production per day is inversely proportional to the production time, i.e. the longer the

production time, the lower the output quantity of the line and the longer the production times required to meet the demand.

- The more operating time available for the production line, the fewer the number of production days required.
- And the shorter the lead time requested by the customer, the fewer the days of production required.

K. Flowchart

Figure 12 shows the quantitative scenario model or flow chart; a production line with 6 activities was developed, which is made up of 21 constants and 30 auxiliary variables.

L. Dynamic Formulation

The standard time per package (1) for each activity is found by means of the direct relationship between the standard time in hours for each unit and the number of units that make up the package.

$$Tstd\ \#\left(\frac{hr*mach}{pack}\right) = Tstd\ \#\left(\frac{hr*mach}{u}\right) * \frac{unit}{package} \qquad (1)$$

Its magnitudes are:
Tstd # (hr *mach /pack); hour*machine/package
Tstd # (hr *mach /u); hour*machine /unit
Unit/package; is the number of units per package. For simulation purposes, we will consider it as 16 units.

Lead Time (LT) per activity (2) is determined by the direct relationship between the standard time of each package and the number of packages. To this, we add the direct relationship between the setup time per machine and the number of machines used for each activity.

$$LT\ activity\ \# = Tstd\ \#\left(\frac{hr*mach}{pack}\right) * ProductionUnit + SetUpTime * \#\,Machine \qquad (2)$$

Production unit; 1 package/machine
Setup time; hour/machine

The hourly production quantity (3) of each activity is the direct relationship of the number of machines per activity by the inverse relationship of the standard time per package.

$$Production\ x\ hour\ \# = \frac{1}{Tstd\ \#\left(\frac{hr*mach}{pack}\right)} * Machine\ \# \qquad (3)$$

Production x hour #; hour/package

The production per day (4) of the number of packages is determined by the direct relationship of the package production per hour to the available operating time per day.

$$Production\ Day\ \# = Production\ x\ hour\ \# * Operation\ time \qquad (4)$$

Operation time; hour/day
Production hour; package/hour
To determine the days required for a given activity (4), the inverse relationship of packages demand per day with the daily production of the activity (n) is required. To this relationship is added the inverse relationship of the unproductive time of the previous activity (n-1) (which is equivalent to the LT of the previous activity) by the operating time assigned to the activity (n) (5).

$$Days\ required = \frac{Demand(paq)}{Production\ Day_n\#} + \frac{Downtime_{n-1}}{Operation\ time_n} \qquad (4)$$

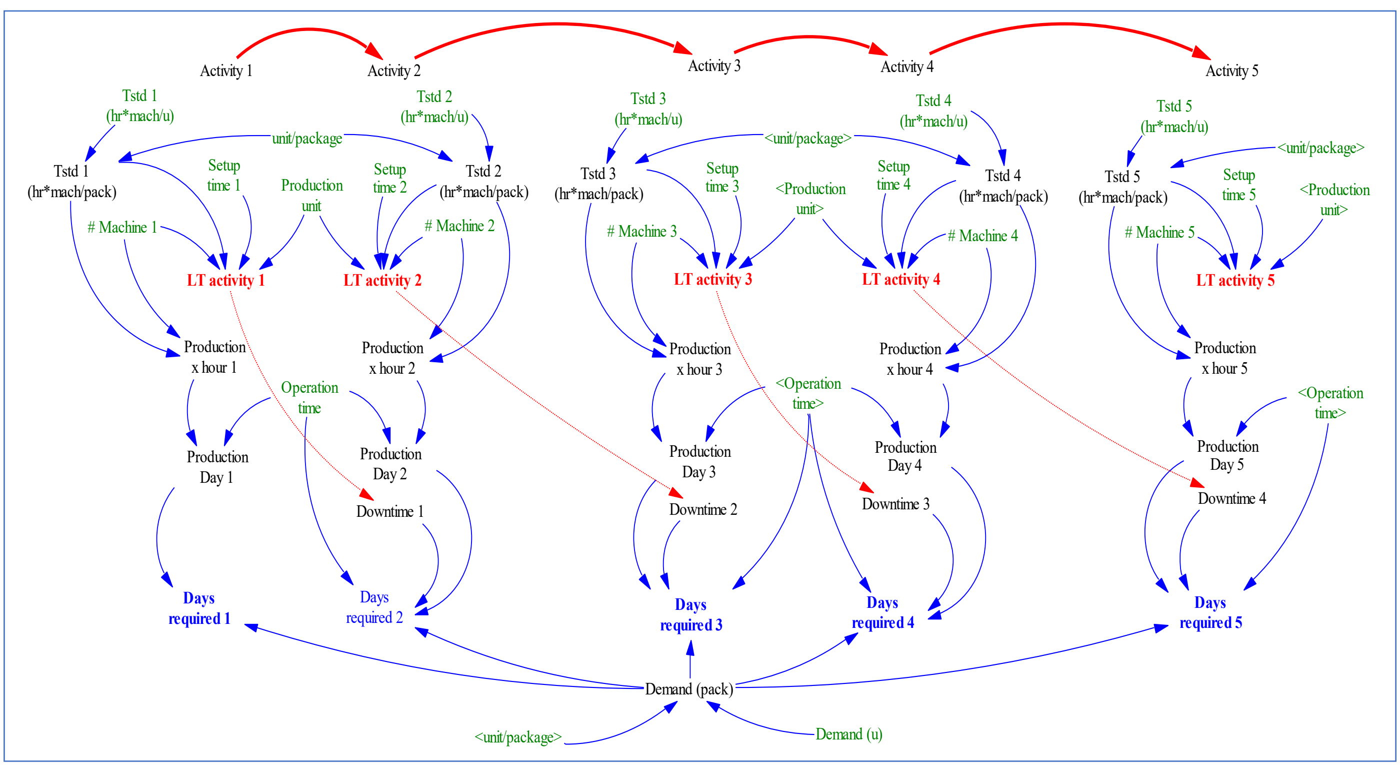

Figure 12: Flowchart

Where:

$$LT\ activity_{n-1} = Downtime_{n-1} \quad (5)$$

III. Results

Figure 13 shows that for a production unit or package formed by 40 units pessimistically, the behavior of the LT processing time increases cumulatively. This is due to the fact that the stations that follow it must wait for the previous station to finish processing its package. This leads to an increase in unproductive times, resulting in a final lead time to the customer of 1.18 days for this production of 310 units, that is, 9.44 hours, when the available operating time is 8 hours.

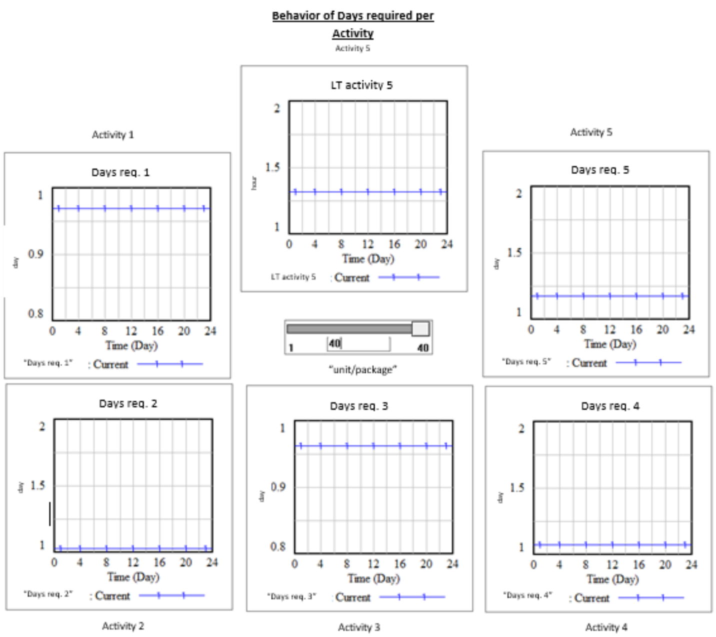

Figure 13: LT behavior for 40 units per package

In Figure 14, for a package consisting of 20 units in normal conditions of line operation, the days required for delivery to the customer was 1.08 days, i.e. 8.64 hours, not meeting the time requested by the customer.

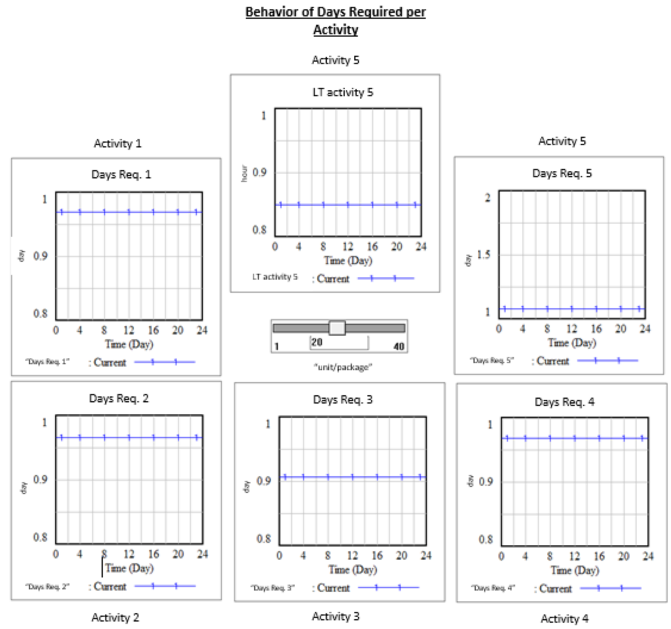

Figure 14: LT behavior for 20 units per package

But if the production line worked with packages of less than 5 units as shown in Figure 15 or by breaking the package, i.e. per unit, it would achieve the goal of delivering 310 units to the customer in one day.

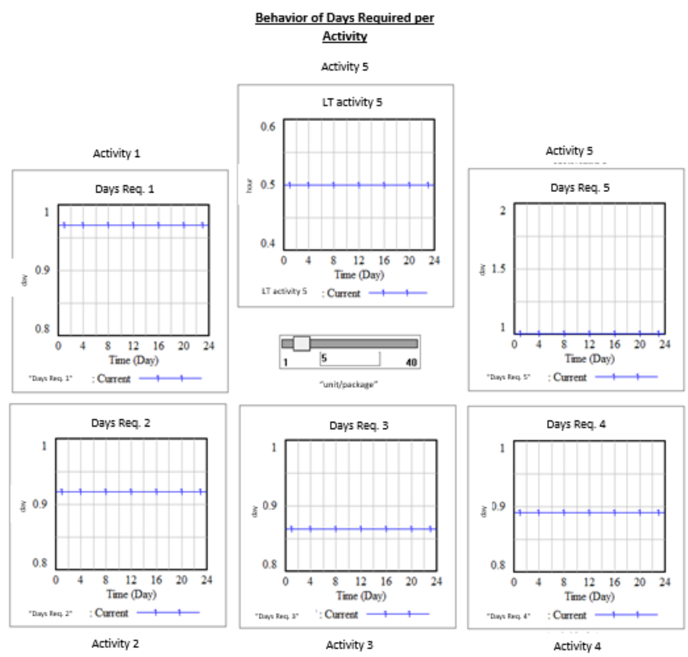

Figure 15: LT behavior for less than 5 units per package.

IV. Discussion

To determine the processing time or LT of the production units that marks the rate of progress of the production areas in the manufacturing sector, it is important to analyze and control from the loading period as well as the cause-and-effect relationship of the variables, as exposed in this research, but this is not disclosed in the research carried out by:

- Dias [33] presents a cooperative strategy between seller and buyer with a constant demand, formulating it as a mixed-integer, nonlinear programming problem to determine the minimum cost considering the following decision variables: reorder point, size of the batch for delivery, number of deliveries and delivery time thresholds.
- Li [34] in his research provides information on practical crop yield forecasting and the understanding of the yield response. It determines the optimum lead time for yield forecasting.
- Kouki [35] presents in his research, heuristically, the effect of shelf life and lead time variability on the system cost and the optimal base stock level.

There is research that validates that the shorter the delivery time of products to the customer, the lower the costs, such as:

- Li [36] explores and quantifies the benefits of lead time reduction. His analytical results show that inventory cost is a strictly increasing concave function of both lead time and its variation.

V. CONCLUSIONS

A smart organization learns from everything that happens to it, listens and acts according to what its customers want and, under the filter of its strategy, acts by quickly modifying its tactics to adapt to its ever-changing environment.

The conceptualization of scenario models by the organization allowed to visualize at a macro level the system in which the manufacturing process is developed for the variety of garment models, observing through experimentation the interaction of cause and effect between variables and constants.

The ordering of variables and constants made it possible to quickly identify, simulate and evaluate which were the limiting variables, due to their causality.

It was quantitatively demonstrated by means of the flow chart that the loading period, with an ever-decreasing setup of production units, has a direct influence on the reduction of production lead times to customers, without neglecting the quality of its processing in each activity.

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