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SENSITIVITY ANALYSIS OF THE IMPACT OF INVENTORY AND CYCLE TIME ON PERFORMANCE OF THE AUTOMOTIVE SUPPLY CHAIN

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Abstract: Decisions the enterprises make about the management of their supply chain is a strategic and complex aspect, which can be the difference between having a competitive advantage or being pushed from the market, so that factors such as inventory management and cycle times of the supply and production are important. For this reason, the present article shows a model under a System Dynamics approach that evaluates, through a sensitivity analysis, the impact of these factors in the performance of the supply chain. Interesting findings from an applied case of a company in the Automotive Cluster of Coahuila are presented.

1. INTRODUCTION

In a dynamic market where the automotive industry operating, assembling factories and suppliers have been forced to improve their processes and products as well as to define strategies to enlarge their warranty time and to offer better after-sale services, so the strategies based only on costs are no longer the base for a competitive advantage.

One of these strategies is to improve in a continuous way the supply chain management of enterprises. Authors like Christopher and Towill (2001), define a supply chain as independent organizations network working in coordination to control, manage and improve the material flow and information from the raw material suppliers to the final customer.

Currently, the automotive supply chain are submitted to many decisions, nevertheless, the variable number and key indicators to consider for the evaluation and development is much extended and complex. In decision making, the people only consider a part of them or the ones they believe are most important, causing a tendency to problem solution or limiting the best solution area, reducing that way the effectiveness of the decision (Oliva and Watson, 2007).

One of the principal Key Performance Indicator (KPI) in the development of the supply chain is the *order fulfillment* and some variables that impact the performance of this indicator are the cycle time and the inventory management.

In this way, this article presents a developed model under approach in System Dynamics, which by a sensibility analysis, evaluates the impact of this variables in the performance of a supply chain belonging to Automotive Cluster of Coahuila.

This article is structured by a *background* section, were a bibliographic review is made about some authors that have worked on the supply chain evaluation and simulation. In *Development of the Model* section, will be exposed the development of System Dynamics model and the *Conclusion* section a result brief synopsis.

2. BACKGROUND

2.1 Supply Chain Analysis

The main objective of a supply chain analysis, is to create initiatives to improve its development, diminishing costs and improving customer satisfaction (Christopher and Towill, 2001), to accomplish this, it is necessary that suppliers, producers and distributors are in constant synchronization of all its activities. However, in the practice, this objective is not always possible to achieve, due to failure in the time agreed and scheduled, the variability of the cycle times in every process of the supply chain as well as the uncertainty that can affect the demand, which are factors that increase the complexity of the problem.

Thus, today there are many techniques and tools used for analyzing, evaluating and decision making in the chain supply management in which there is simulation, is an effective tool in production operation and logistic systems in which the main strength compared with math programming methods or stochastic models is that lets the user to observe, analyze and learn the dynamic behaviors system (Umeda and Tina, 2004). Among simulation types for supply chain, five are the most important: i) Simulation on Calculation Sheet; ii) System Dynamics; iii) Simulation Discrete Events; iv) Dynamical Systems; and v) Business Simulators.

Inside the five simulation types mentioned above, System Dynamics methodology up stands for its easy representation of time delays that allow seeing the system behaviour under a study (Angerhofer and Angelides, 2000).

2.2 Supply Chain Models under a System Dynamics approach

The System Dynamics methodology was developed by Jay Forrester, a researcher of the MIT in the beginning of the 60`s, because of its interdisciplinary focus, it helps to understand the dynamic characteristics of a complex system, being the causal loop diagrams the main tool. (Stemarn, 2000).

Some authors have developed simulation models using this methodology, where they consider as an important part the cycle time that affect de performance of supply chain. For example, Ritchie-Dunham et al (2000) developed a model to analyze planning strategies of resources on a supply chain; Umeda and Tina (2004) propose a simulator to analyze the specification design on a supply chain; Georgiadis, Vlachos and Iakayou (2005) analyze strategies for a supply chain on the food industry where the transportation and delivery time is an important factor; Kamath and Roy (2007) analyze the increasing capacity of a supply chain in which the life time of the product is short, considering among relevant variables the time adjustments of production for fast response to the demand due to life characteristics of the product.

3. DEVELOPMENT OF THE MODEL

3.1 Case Study

The automotive industry in Mexico is important for the national economy, because represents the 24.5% of Gross Domestic Product (GDP) and 20% employment of manufacturing sector where 21.4% of automotive productions is dedicate to exports (AMIA, 2008). Actually, Mexico is considered as an important member of the international network of automotive production. Important assemblers as Chrysler, Ford, General Motors, Nissan and Volkswagen have success operations in Mexico. Concerning to the states with presence of automotive industry, up stands the state of Coahuila which produced in 2007, 37.4% of automobiles, 62.6% of trucks and 51.5% on national motor production (AMIA, 2008).

The composition of automotive cluster from Coahuila is structured by two assemblers and their Tier 1 suppliers, in which most of them are global corporations (Cedillo, Sanchez and Sanchez, 2006).

Our case study was focus on the factory called ABC that belongs to a supply chain of Automotive Cluster from Coahuila. Because of the high customer demand, this production site wanted to analyze the affectation on this high demand in the accomplishment and its supply chain. Figure 1, shows the behaviour expected on the demand in 52 weeks.

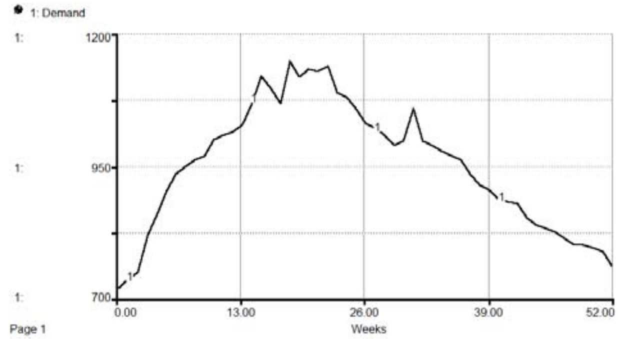

Figure 1**.** Behaviour of demand on the next 52 weeks

3.2 Causal Loop Diagram

To structure the causal model and subsequently make the model to be simulated, our research considered models proposed by Georgiadis, Vlachos and Iakayou (2005), and Kamath and Roy (2007).

The model has been divided in three processes for a better comprehension: i) Supplying, ii) Production and iii) Distribution, and Evaluation. The principal variables of each process are:

Supplying:

- *Inventory of RawMaterial:* Inventory level of available material for the production process.
- *Ordering to Supplier:* Indicates when a raw material order has been generated to the supplier.
- *Delivery Time:* Time that the supplier takes to put the order.

Production:

- *Production capacity:* Maximum capacity that the company can produce with available resources.
- *Cycle Time:* Time processing of the raw material in Finished Good.

Distribution and evaluation:

- *Demand:* Customer requirements
- *Evaluation:* Difference between the requirements of the customers and what the company supplies of those requirements.
- *Inventory of Finished Good:* Inventory level of finished product used to supply the orders.
- *Shipment:* Orders supplied to customers.

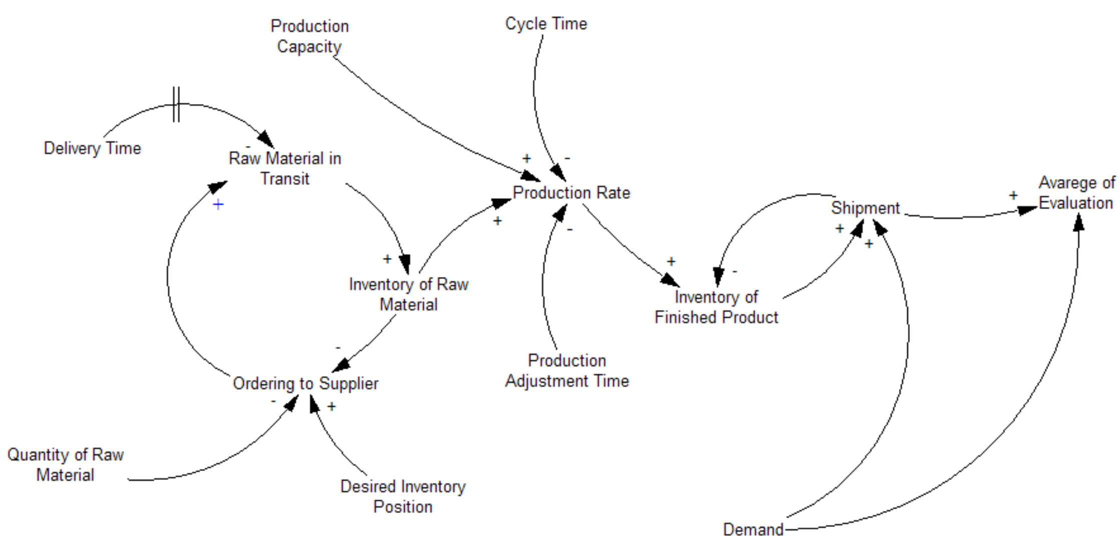

Figure 2. Causal Loop Diagram

4. RESULTS AND ANALYSIS

4.1 Base for Model Simulation

The model developed in STELLA 9.0.3 was simulated during 52 weeks with the demand presented on figure 2. Among the assumptions considered in this model was the following, the order point and the quantity of raw material is constant when an order is generated; the raw material warehouse has a maximum capacity of 8,500 units; the production capacity has a normal distribution behaviour with a mean of 1,300 units and a standard deviation of 30 units; the finished good warehouse has a capacity for 5,000 units.

Table 1, shows the actual values and results obtained in the simulation during the 52 weeks; as it can be observed it would only have in average 69.1% in the fulfillment orders.

Figure 2, shows the behaviour of the raw material warehouse and the ordering to supplier.

Table 1. Values and Initial results of the model

Variables	Initial Values	Results
Delivery Time of Raw Material	3 weeks	*
Cycle Time	1.5 weeks	*
Adjustment Production Time	3 weeks	*
Raw Material Warehouse	1,500 units	6, 682 Units
Supliré Lot	7, 500 units	*
Order Point	2, 500 units	*
Finished Good Warehouse	1, 200 units	361 Units
Number of Ordering to Supplier	0	6
Average Fulfillment Orders	0	**69.1 %**

*** They remain constant**

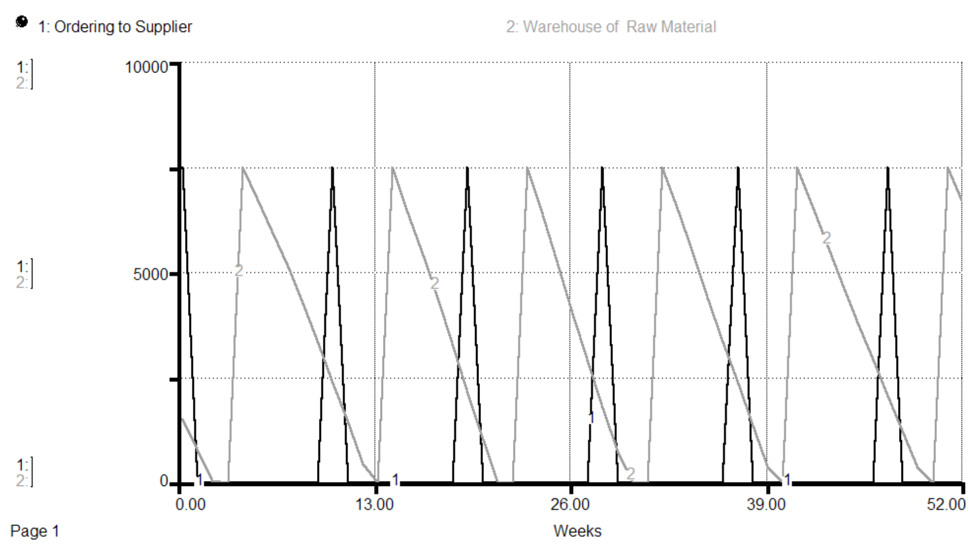

Figure 3. Behaviour of raw material warehouse and ordering to supplier

4.2 Analysis of Sensibility and Results

As shown in table 1, the company would not fulfilment the customer's orders if it would confront this new demand with the actual values that has in its processes. Due to the said before, in this section a sensibility analysis is presented with the objective to find the values in the processes that would allow the total fulfillment orders. Table 2, shows the results of sensitivity analysis with the following values:

Cycle Time (CT)= 1.5 *weeks*
Production Adjustment Time (PAT) = 1, 2 and 3 weeks
Delivery Time (DT) = 1, 2 y 3 weeks
Inventory Raw Material (IRM) = 1000, 2000 and 3000 units
Inventory Finished Good (IFG) =1000, 2000 and 3000 units

Table 2 shows that the average fulfillment orders would increase to ***99.13%*** with the following values *CT=1.5*, *PAT=1*, *DT=1*, *IFG=3000* and *IRM=2000*, nevertheless, it can't be fulfillment the 100% of the orders. For this reason, the table 3, shows the results obtained with the policy, with the following values:

Cycle Time (CT)= 1 *week*
Production Adjustment Time (PAT) = 1, 2 and 3 weeks
Delivery Time (DT) = 1, 2 y 3 weeks
Inventory Raw Material (IRM) = 1000, 2000 and 3000 units
Inventory Finished Good (IFG) =1000, 2000 and 3000 units

Table 2. Results obtained with a Cycle Time with *CT* of 1.5 weeks

			CT=1.5								
			PAT= 1			PAT= 2			PAT= 3		
			IRM			IRM			IRM		
			1000	2000	3000	1000	2000	3000	1000	2000	3000
DT= 1	IFG	1000	92.39	94.34	94.21	92.03	92.35	92.21	91.52	92.34	92.14
		2000	94.97	96.92	96.8	94.61	94.94	94.79	94.40	94.92	94.72
		3000	97.28	99.13	99.00	96.91	97.15	97.01	96.70	97.14	96.94
DT= 2	IFG	1000	85.55	87.73	88.34	85.50	87.68	88.27	84.21	86.39	88.21
		2000	88.13	90.31	90.93	88.08	90.26	90.86	86.79	88.97	90.79
		3000	90.43	92.54	93.13	90.38	92.5	93.07	89.09	91.21	93.01
DT= 3	IFG	1000	77.59	79.76	80.00	77.54	79.71	79.97	77.48	79.66	79.92
		2000	80.17	82.35	82.58	80.12	82.3	82.55	80.07	82.25	82.51
		3000	82.47	84.58	84.79	82.42	84.53	84.76	82.37	84.48	84.72

Is possible to fulfillment the 100% of the orders (see table 3), with the following values *CT=1*, *PAT=1*,*DT=1*,*IFG=3000* and *IRM=2000* and *CT=1*, *PAT=1*,*DT=1*,*IFG=3000* and *IRM=3000*. The constrains of the warehouse were observed (see figure 4).

Table 3. Results obtained with a Cycle Time with *CT* of 1 week

			CT=1								
			PAT= 1			PAT= 2			PAT= 3		
			IRM			IRM			IRM		
			1000	2000	3000	1000	2000	3000	1000	2000	3000
DT= 1	IFG	1000	94.78	96.78	96.75	94.62	94.98	94.85	94.32	94.90	94.69
		2000	97.24	99.15	99.12	97.09	97.35	97.22	96.79	97.27	97.06
		3000	99.18	100	100	99.13	99.17	99.04	98.86	99.17	98.96
DT= 2	IFG	1000	87.33	89.61	90.22	87.29	89.58	90.16	85.91	88.2	90.11
		2000	89.79	92.02	92.59	89.76	91.99	92.53	88.38	90.61	92.48
		3000	99.02	93.94	94.41	91.99	93.93	94.4	90.61	92.59	94.4
DT= 3	IFG	1000	79.59	81.87	82.24	79.54	81.83	82.21	79.49	81.87	82.16
		2000	82.05	84.28	84.61	82.01	84.23	84.58	81.19	84.19	84.53
		3000	84.28	86.39	86.63	84.23	86.35	86.62	84.19	86.3	86.58

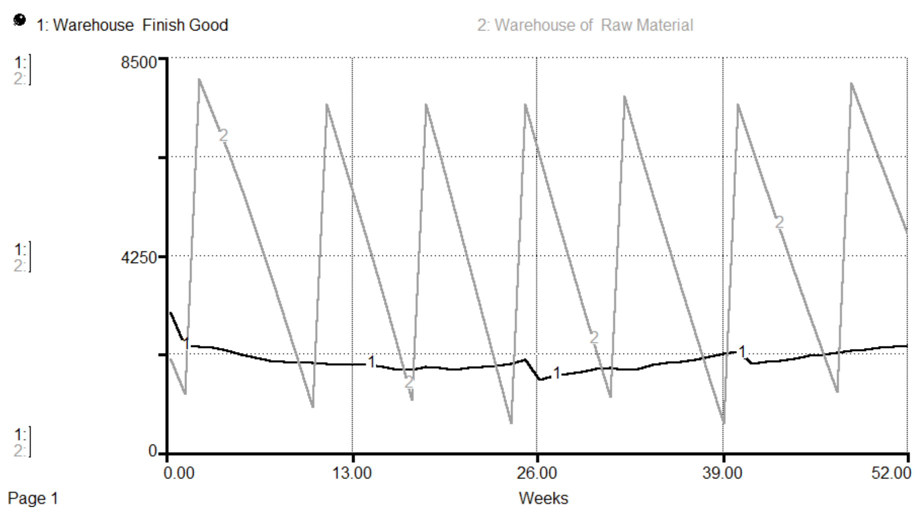

Figure 4. Behaviour of Warehouse of Raw Material and Finished Good

5. CONCLUSIONS AND FUTURE WORK

Because of the dynamism of automotive sector, the companies that belong to supply chains are submitted to a numerous decision making, in which the main objective is to define strategies to improve the products and services offered to the customer, as well as the fulfilment orders. Thus, this article presented the case study of a company belonging to the Automotive Cluster of Coahuila, which wanted to analyze the impact of the increasing of this demand in the development of their processes, for this reason, a model under an approach in System Dynamics was developed, and the impact is analyzed with the support of a sensitivity analysis to the cycle times and inventories, the best politics in the processes were identified and must have this variables to fulfilment of the total orders. This results are being taking into account for future work to extend the model with a cost analysis; which will allow identifying the economical impact in the development of supply chain of automotive companies operating under emergent markets context.

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