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PERFORMANCE ANALYSES OF CONWIP – BASE STOCK CONTROLLED PRODUCTION SYSTEM USING SIMULATION

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Abstract: *The objective of this paper is to develop a simulation model to study the performance of a typical single line multistage pull production system namely, Conwip – Base Stock. The customer demand, holding cost rate and setup number have a exponential distribution between: 160 and 360 products/day, 12 and 35 % and 2 and 8 setups. The entire manufacturing line was simulated for 825 hours, which include 75 hours warm – up period. The performance measure is total cost. The simulation results indicate that the setup numbers have a smaller influence on the total cost and the influence of demand and setup number is approximately equal.*

Keywords: Base stock, Conwip, performance, production system, simulation.

INTRODUCTION

Even in the late 1800's when vehicle manufacturing production started to develop, it was characterised by high quality manual production, although very expensive, low productivity and addressing to a small range of consummers, the need to move to mass production was felt. Thus, in the 1920's Henry Ford launched the mass production for vehicles. It was characterised by assembly lines with low skilled workers who made hundreds of identical low quality products but at accesible prices for an family of avaerage condition.

As we know mass production in all fields was developed so much that after the 1980's the value of the products for the customer was given by low costs, availability of high quality products and producers' flexibility to produce in accordance to the demands of the market. Since the year 2000 the products value for customers is given by production flexibility, high quality combined with low costs and availability. In other words, if companies want to survive in a global market, they need to have profit, renewed contracts and economic growth. In order to do so, companies have to be the best in delivering quality products at competitive prices and within shorter terms than their competition.

The methods to control a pull type production lead to reducing the stocks significantly and at the same time they lead to reducing the costs by diminishing the 7 types of losses [1]:

- processing losses;
- overproduction losses;
- inventory losses;
- motion losses;
- defects losses;
- waiting losses;
- transportation losses-

The demands for the methods to control a pull type production flow tend to implement a production system where the factors have the following tendencies:

- zero tolerance for waste;
- zero setup time;
- zero inventory cost;
- zero machine failure;
- one piece flow.

The implementation of these tendencies is based on three basic principles:

- producing the parts only at customer's demand, at the time, in the quantity and with the quality required;

- manufacturing some groups of products in a continuous flow;
- creating flexible production systems. Machines can produce a group of products without being changed by operators.

The simulation, modelling and analysis of manufacturing systems for performance improvement have become increasingly important during the last few decades. Modern computer aided simulation and modelling tools help to visualize, analyze and optimize complex production processes using computer animations within a reasonable amount of time and investment**.**

Simulation was used in studies because of two main reasons. First, it was used to assess the compared performances between the pull flow system and other types of systems, for example systems with order points of manufacturing ROP, and push flow systems [2], [5]. Second, it was used to identify the determining factors to implement successfully the pull flow system [1], [3], [4].

Thus, discrete-event simulation is an important tool for evaluating different production control policies. Moreover, finding a production control policy that achieves the best tradeoff between customer service, work-in-process inventory, cost and other performance measures is a difficult task.

Next we will present and analyze the performances of a production system controlled with the help of the Conwip – Base control method through total cost.

DEVELOPMENT OF SIMULATION MODEL

The conceptual model

The models of the system were built according to the descriptions previously given a few assumptions were made to simplify the simulation process. The most important assumptions were the following:

- *number of products* – two products, PA and PB;
- *the technological process* needed for product manufacturing, that implies the same sequence of operations, table 1.

Table 1. The sequences of stage

No.	**Stage**	**Number of workstations**
1	Turning	1
2	Gear cutting	1
3	Chamfering	1
4	Brush gear	1

In order to accomplish the operations within the technological process a single machine is needed for each type of operation; the machines are placed in the order of accomplishing the operations within the manufacturing process.

- *processing time*, table 2
- *machine failure – down time*, table 2
- *changeover time* , table 2
- *setup time, table 2*
- *the time needed for the operator's lunch and rest*, table 2;
- *machine failure – up time*, table 2 - it shows the average time of good operation until a failure reappears, or the average time of good operation until a failure appears or between two successive failures, table 2;
- *the running time of a tool* – it is given by the longevity of a tool and is specific to each type of tool, table 2
- *setup cost* – 129.05 [u.m./h]
- *production cost* - 96.5 [u.m./h]

Table 2. Production cycle times

No.	Stage	Processing time [mi/op.]		Breakdowns			*The time needed for the operator's lunch and rest* [mi/day]	*Machine failure – down time* [mi]	*The running time of a tool* [mi]
		Product PA	Product PB	*Machine failure – up time* [mi]	Setup time [mi]	*Changeover time* [mi]			
1	Turning	1.89	1.89	15	5	3.1	60	1002	378
2	Gear cutting	1.96	1.93	28	11	7.0		1083	7840
3	Chamfering	2.76	2.7	5	9	5.4		1231	29000
4	Brush gear	3.4	3.38	8	11	6.0		2195	19750

The simulation model

The operating modulus of the Conwip – Base stock model is presented in figure 1. Queue *Bi* represents the production buffers of stage *i* and contains both the finite elements of stage *i* at a level corresponding to the base stock and the conwip card. Queue D_i contains the demand and queue *C* contains the conwip cards of the system. Their movement within the system is shown by the green line and the movement of the demand is shown by the red line.

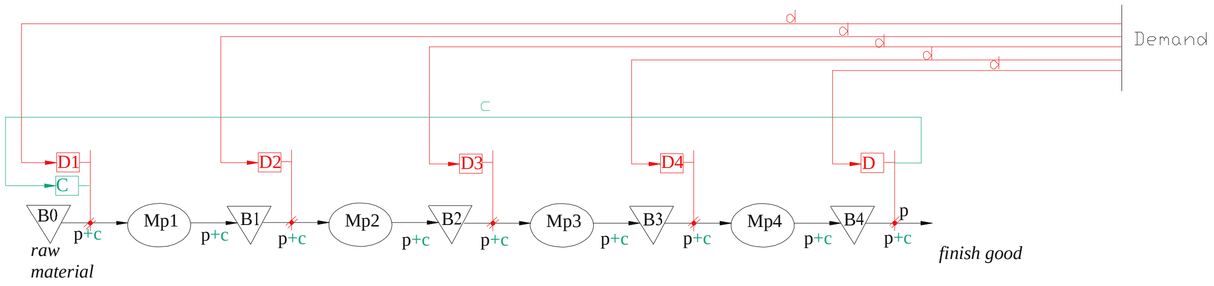

Figure 1 Conwip - Base stock method

When the system is in an initial phase, queues B_i , $i = 1 \ldots N$, have *Si* finished parts with conwip cards attached, representing the level of the base stock, the other queues are empty.

The system controlled with the help of the Conwip – Base stock method functions as follows. When the customer's demand arrives at the system it is divided into N+ 1 demand, each one being transferred in queue Di and the last one joins queue D requesting the release of a finished product from B_5 to the customer. When the demand reaches queue D there are two possibilities:

- If a part is available in B_4 (which is initially the case), it is released to the customer immediately after detaching the conwip card that will be transferred to queue C authorizing the release of raw stock.
- If there is no part available in B_4 the demand is backordered and waits until a new finished part reaches B_4.

For other stages beside the last stage, they will operate in the same way as in a system controlled with the help of the Base stock method. When the demand reaches queues Di there are the following possibilities:

- If a part is available in Bi, it is immediately sent to the following stage i+1 and stage i produces another one to balance the base stock, or to the customer for the last stage satisfying the demand.
- If there is no part available in buffer Bi, the demand is backordered and waits in queue Di until a new part from the upstream stages is available.

The raw stock is released from buffer B_0 only when there are both cards in C and demand in D1. Thus, the information about the customer's demand is transferred upstream through the system with the help of the Base stock method and towards the first stage through the CONWIP card.

The CONWIP – Base Stock method is a hybrid control mechanism that depends only on one parameter per stage, namely *Si*, $i = 1 \ldots N$, and one additional parameter for the entire system, *CA/CB*.

The level of the base stock will be the same during all working stages and its value depends on the customer's demand, table 3.

Tabel 3. Base stock

Demand	360 products	240 products	160 products
S_i – base stock	**45**	**30**	**20**

In the model there will circulate 4 conwip cards, CA, for product PA and 4 conwip cards, CB, for product PB.

When a machine fails during a working stage, the demand process will continue to remove parts from the base stock and the downstream machines will work normally until they will need new parts. The upstream stages continue to receive information concerning the demand directly and they will operate and send parts in a normal way. So they will not be connected to restoring the stock in the stage where the failures appeared.

EXPERIMENTAL

Following the experimental researches regarding the dependence of the total cost on the demand, holding cost rate and setup number, we have established that the main cost total can be expressed by a relation, such as:

$$C_T = a \cdot D^b \cdot {t_S}^c \cdot {n_R}^d \tag{1}$$

where a, b, c, d are constant and D, ts and n_R represent the demand, the holding cost rate and the setup number.

This dependence may be linearized by logarithmation:

$$\lg C_T = \lg a + b \lg D + c \lg t_S + d \lg n_R \tag{2}$$

By substituting: $\lg(F_z) = Y$; $\lg(a)=A_o$; $b=A_1$; $\lg(D)=X_1$; $c=A_2$; $\lg(ts)=X_2$, $d=A_3$; $\lg(n_R)=X_3$ we obtain the linear equation (3).

The values X_1, X_2, X_3 are known to be imposed values, and the value Y is measurable. In order to determine the equation one has to determine the A_0, A_1, A_2 and A_3 coefficients.

If the relation of dependence $Y = Y(X_1, X_2, X_3)$ can be expressed by such an equation:

$$Y = A_o + A_1X_1 + A_2X_2 + A_3X_3 \tag{3}$$

then Y depends linearly on the X_1, X_2, X_3 variables.

This equation represents the mathematical model chosen to characterize the process or the phenomenon. One can reach the linear dependence of a value with many variables through mathematical artifices.

Starting from the data presented in table 4, meaning the admission parameters of the process, we have established an experimental factorial and fractional plan of the type 2^3. This plan is presented in table 5.

Table 4. The values of the admission parameters of the process

The parameter		The real value	The normal value
Demand [EA]	D_{min}	160	-1
	D_{med}	240	0
	D_{max}	360	1
Holding cost, [%]	ts_{min}	3.5	-1
	ts_{med}	2.35	0
	ts_{max}	1.2	1
Number of setup	n_{Rmin}	2	-1
	n_{Rmed}	4	0
	n_{Rmax}	8	1

Table 5. The experimental plan

Exp.	The standardized values of the independent variables		
	D	ts	n_R
1	-1	-1	-1
2	1	-1	-1
3	-1	1	-1
4	1	1	-1
5	-1	-1	1
6	1	-1	1
7	-1	1	1
8	1	1	1
9	0	0	0
10	0	0	0
11	0	0	0
12	0	0	0

The total cost is directly determined by simulations. After simulation the experimental data, table 6, obtained on the basis of the research plan presented in table 5, an empiric relation was obtained in what concerns the influence of the demand, holding cost rate and number of setup on the main cost total.

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Table 6. The values of the independent variables and those obtained for the dependent variable

Exp.	**Real value**			**CT**
	D	t_S	n_R	
1	160	0.12	2	281104.21
2	360	0.12	2	320907.98
3	160	0.35	2	348491.92
4	360	0.35	2	425828.23
5	160	0.12	8	290611.03
6	360	0.12	8	323646.48
7	160	0.35	8	348552.46
8	360	0.35	8	406570.93
9	240	0.204	4	333071.52
10	240	0.204	4	333103.51
11	240	0.204	4	333021.76
12	240	0.204	4	323199.29

The relation obtained after working on the data in table no. 6 is:

$$C_T = 10^{5.23754} \cdot D^{0.18327} \cdot t_S^{\,0.21198} \cdot n_R^{\,-0.00078} \qquad (4)$$

Based on the regression relation obtained we have drawn diagrams of the type $lgC_T=F(lgD)$, $lgC_T=F(lgts)$, $lgC_T=F(lgn_R)$, these diagrams point out the influence that each input parameter has on the output parameter. These diagrams are presented in the following figures.

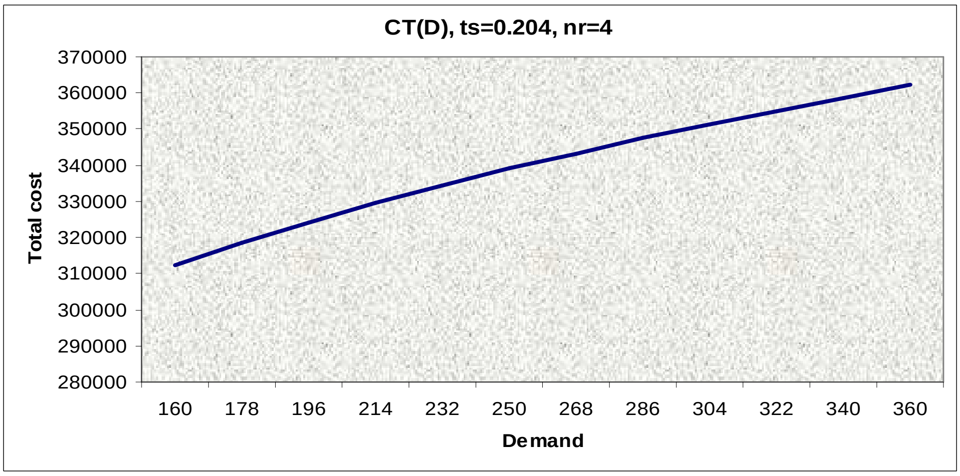

fig. 1 Graphs $lgC_T = f(lgD)$

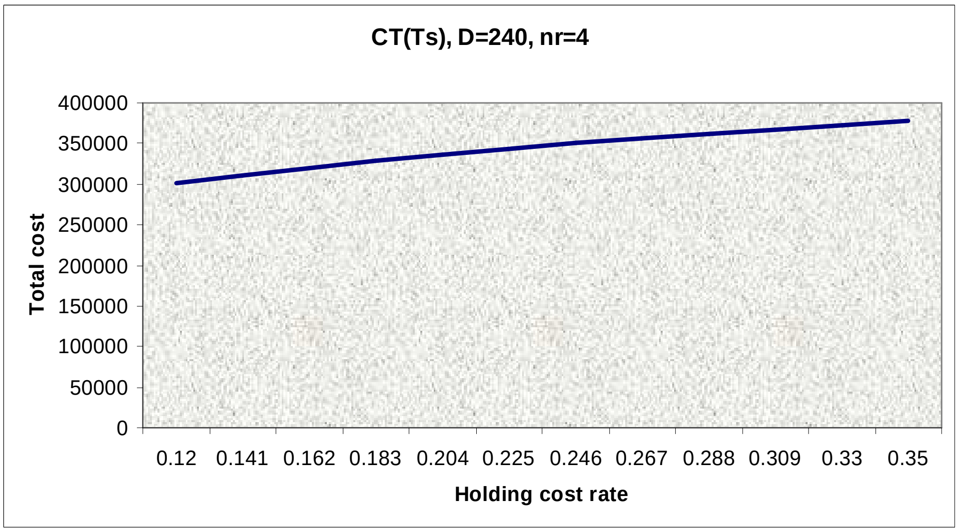

Fig. 2 Graphs $lgC_T = f(lgt_S)$

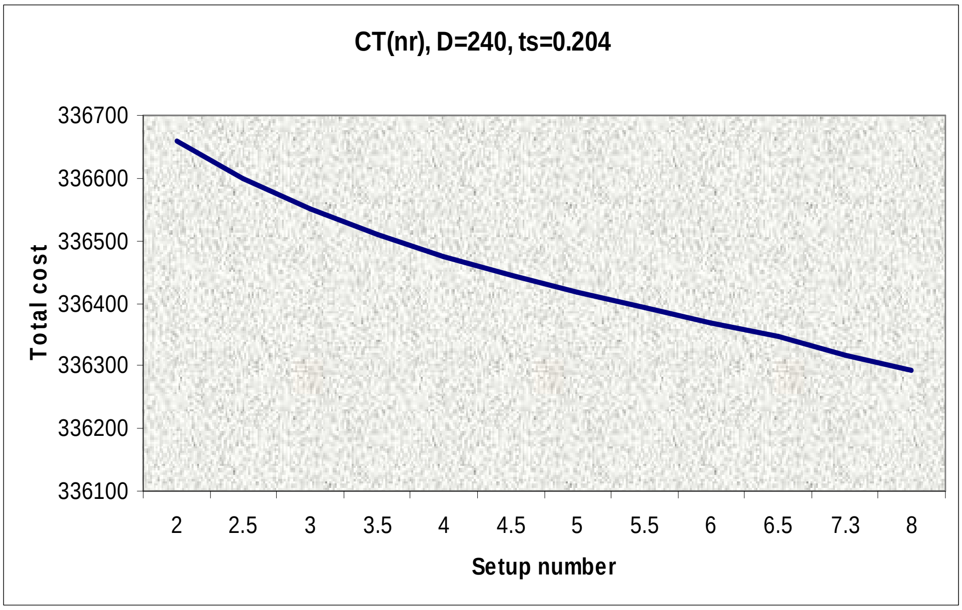

Fig. 3 Graphs $lgC_T = f(lgn_R)$

The influence of each input value on the total cost can be pointed out through such graphs as $lgC_T=F(lgD)$, $lgC_T=F(lgts)$, $lgC_T=F(lgn_R)$, connected to those corresponding to the two remaining values, using the minimum and maximum values; the graphs that indicate the dependences $lgC_T=F(lgD)$, $lgC_T=F(lgts)$, $lgC_T=F(lgn_R)$, associated to the dependences corresponding to the two remaining values

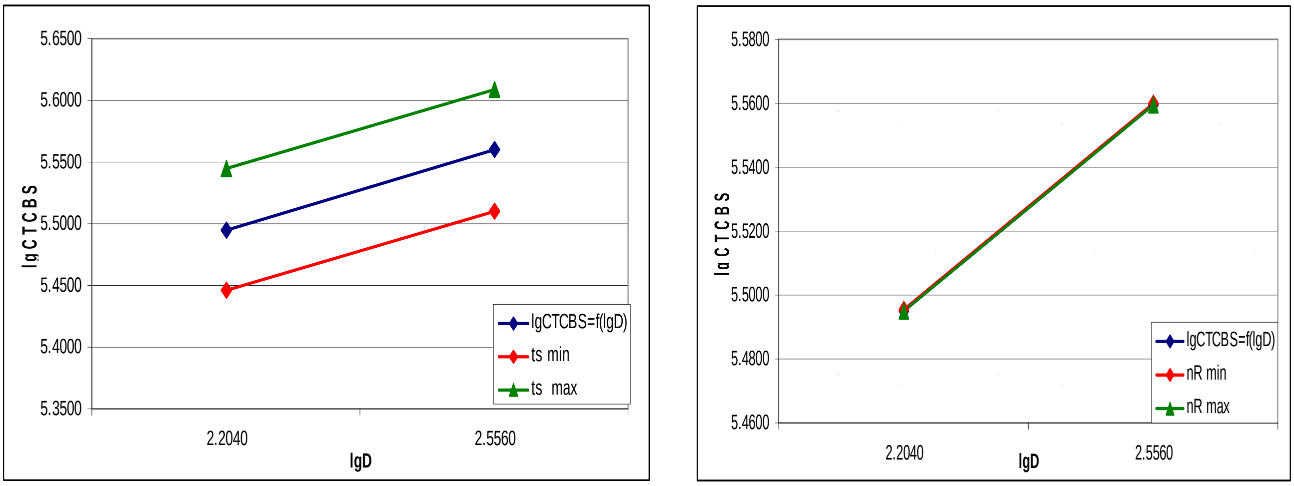

Fig.4 Graphs $lgC_T=f(lgD)$

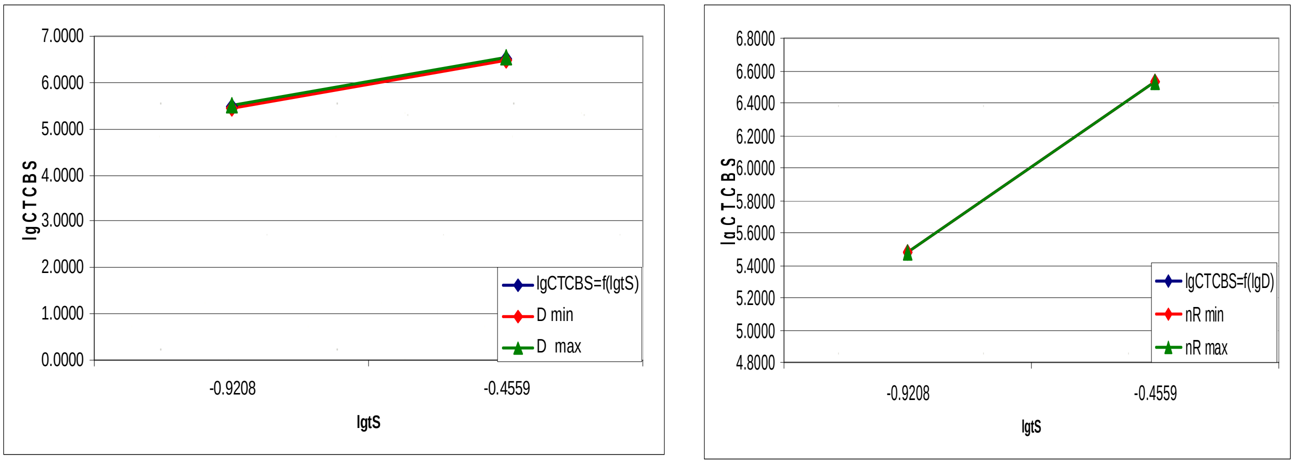

Fig. 5 Graphs $lgC_T=f(lgt_S)$

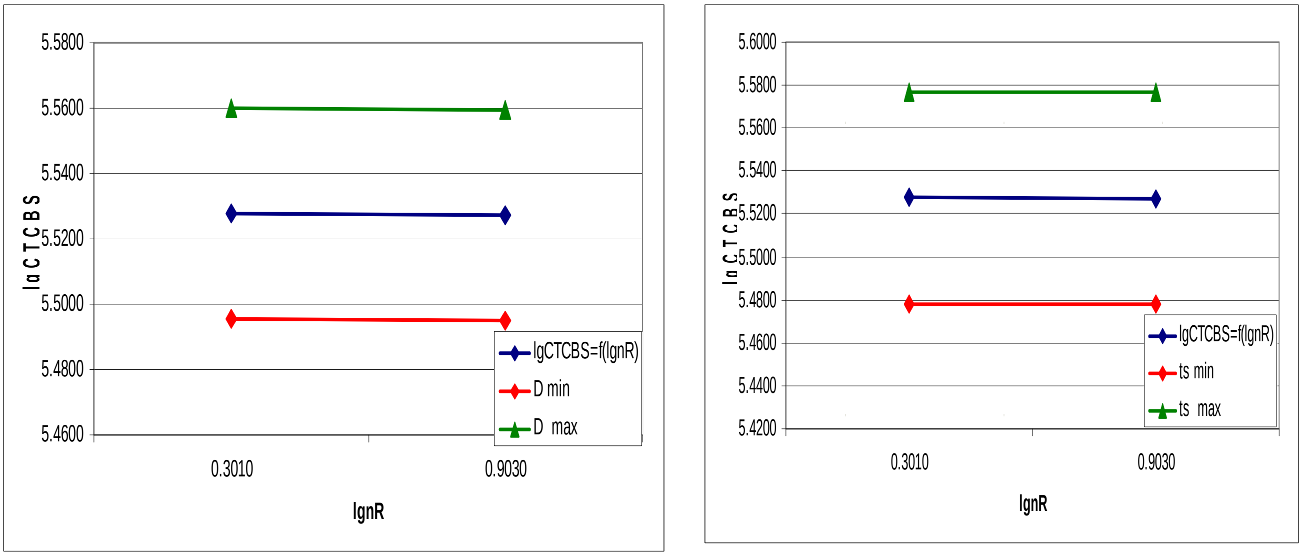

Fig. 6 Graphs $lgC_T=f(lgn_R)$

CONCLUSIONS

By analysing the figures 1, 2 and 3 above we observe that the setup number have a smaller influence on the main total cost. Another observation is that the influence of the demand and of the holding cost rate is approximately equal.

Following the experiments of the research plan and the analysis of the data obtained we issue the conclusions following:

- the order of the influence of the input parameter on the output parameter is: the holding cost rate, the demand and setup number
- the value of the total cost represents one of the assessing criteria of a production system's performances; this is why this study can be useful in choosing a production control method;
- the function of the total cost determined, valid for all the characteristics of the system taken into consideration, as well as the results obtained, represent a set of data meant to help one establish the values of some parameters of the system in order to achieve certain values of the total cost, thus, making possible the optimizing of the system.

REFERENCES

[1]. Chase, Richard, Nicholas Aquilano and Robert Jacobs, 1998, *Production and Operations Management*, Manufacturing and Service Eighth edition. New York: Irwin McGraw-Hill.

[2]. Kimura O. and H. Terada, 1981, *Design and Analysis of Pull System, a Method of Multi-Stage Production Control,* International Journal of Production Research 19

[3]. Krishnappa, A. R., *Simulation Study of a Kanban Controlled Production System*, Morgantown: West Virginia University, 1999.

[4]. Sarker, B., and Roy, D. Harris, *The Effect of Imbalance in Just-In-Time Production Systems: a Simulation Study,* International Journal of Production Research 26, 1988.

[5]. Sarker, B. and J., Fitzsimmons, *The Performance of Push and Pull Systems: a Simulation and Comparative Study*, International Journal of Production Research 27, 1989.