"NEW PRODUCTION PLANNING SYSTEMS: A SYSTEM DYNAMICS PERSPECTIVE"

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ABSTRACT

This paper describes the evolution of production planning systems under the system dynamics approach. The structure, feedback loops and decision making process are analyzed under different "pull" & "push" operation management techniques such as order point, base stock, MRP, KANBAN, etc. The study is made in chronological order, with the main objective being pointing out the procedures of controlling the system's behaviour, arisen from the new production technologies development. Simulation results are presented for several cases.

1.- INTRODUCTION.

The replenishment approaches in operation management stood until the middle of the XX century. These methods tried to assure the stock level in the production components inventory for all processes (Swan, 84). After the fifties, the trends and viewpoints in manufacturing techniques began to change. An important change was the idea of only keeping the stock strictly needed.

The settlement of the order point is the first step in the development of the modern "pull" manufacturing techniques. This method calculates the point where a component should be ordered so that the stock during the component supply time does not run out. The demand "pulls" the production from the final stage once the inventory level is lower than the order point value calculated.

A second step in "pull" production methodologies (Karmarkar U.S., 86) is the base stock control principle. Here, the order point is fixed taking into account the work in process inventory as well.

On the other hand, the evolution of "push" techniques acting simultaneously can be noted (Domínguez Machuca & García González, 91). Since the late fifties, approaches that link component reliance or dependence on each other, inventory levels and replenishment orders have appeared. All these processes lead to the Material Requirements Planning (MRP), which can schedule the specific production requirements, using an appropriate computer programme.

Finally the JIT-KANBAN system (Ohno T., 88) introduces a new concept in manufacturing control. A mix of simple "pull" and "push" effects. This system can be considered a hybrid system and promotes a real change in the factories.

This paper deals with the evolution mentioned above under a system dynamics perspective. In the models considered, (order point, base stock, MRP and JIT-KANBAN) the effects of every innovation in the production system dynamics are described.

2.- AN ORDER POINT MODEL.

Models for this pull technique have been widely described previously (Morecroft J., 83). For this study's purpose, one of the stages of the production line could be represented by an influences diagram as follows:

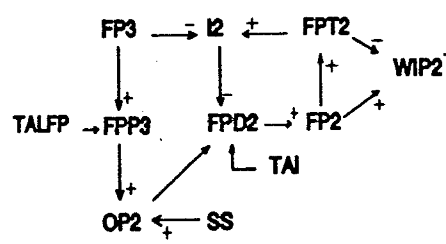

Figure. 1. Influence diagram of a production stage in the order point model.

In the sub-assembly sub-unit shown in Figure 1. the decision making process calculates the value of the variable order point (OP2).

The negative feedback loop identified in figure 1 is shown in more details in figure 2.

This negative loop is a fourth order loop with a total delay of LT2+TAI, where:

LT2 = Lead time of the second process(subassembly).

TAI = Inventory adjustment time.

The gain between the stage's inventory (I2) and the desired order rate (FPD2) is -1/TAI. Models such as those studied for manufacturing control are of "goal-seeking" type, and therefore, a negative loop like that described above is positive.

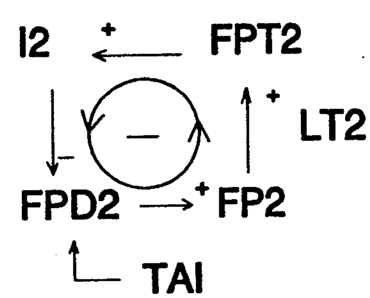

Figure. 2. Negative loop in the order point model.

Problems appear when the lead time (delay in production) increases towards values where, for the decision making process, a variation in the input signal (now FP3, real demand in the case of the assembly process inventory) takes too long to be taken into account. Another possibility is that a bad selection of the TAI parameter could produce an undesirable amplification.

Examples of these situations are shown in figures 3 and 4 for a 10% increase of demand. The undesirable effects of fluctuation appear as soon as the lead time begins to increase with amplification proportional to (1/TAI).

With the following figures the behaviour of the model can be appreciated for values:

LT=0.5 days and TAI = 1 day . (Figure 3).

LT= 1 day and TAI =0.5 days. (Figure 4).

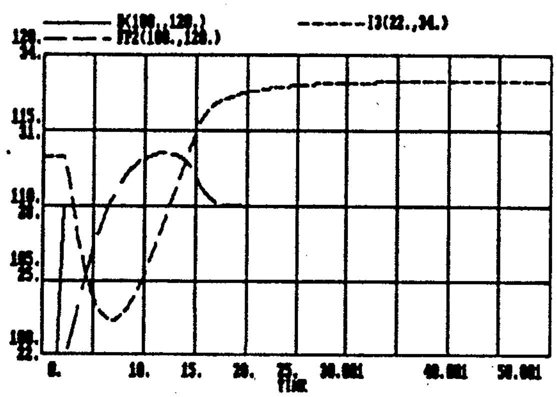

Figure. 3. Order point model simulation.

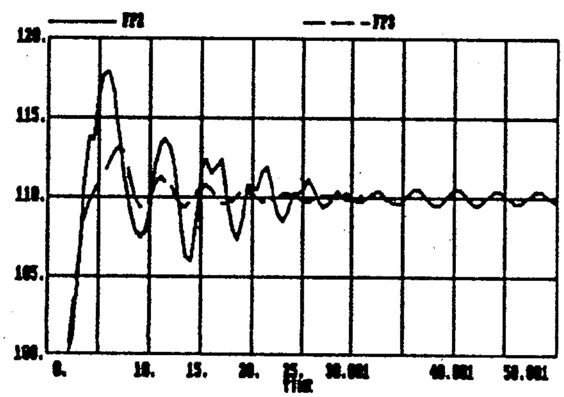

Figure. 4. Order point model simulation.

3.- A BASE STOCK MODEL.

As commented previously, the base stock management is a step ahead in the development of pull production techniques. The new control methodology can now be observed. The new influence diagram is shown in figure 5.

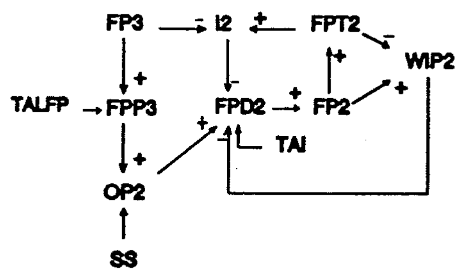

Figure. 5. Influence diagram of a production stage in the base stock model.

In this model the work in process inventory (WIP2) plays a new role. It acts as a controller level when the desired production rate is calculated (FPD2), adding its effect to those of the final stage inventory (I2), which is also taken into account in the order point model. In the new situation, two more loops appear and modify the system dynamics behaviour. These loops are shown in figures 6 and 7.

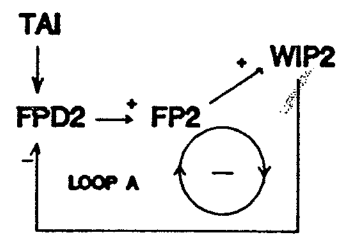

Figure. 6. Second negative loop in the base stock model.

Figure 6 shows a negative loop of fourth order and a total delay of LT2+TAI. The final stage inventory (I2) controls and regulates the desired production rates. It is appropriate for a goal seeking model like this one.

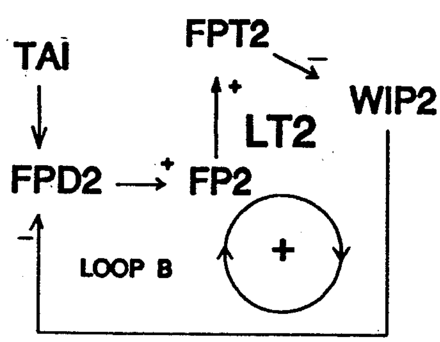

Figure. 7. Positive feedback loop in the base stock model.

The third and new loop introduces an undesirable positive feedback effect in the model. Loop's gain and delay are equal to that of the former loop. The effect of this loop is simultaneous to the one shown in figure 6, so that growth is not pure, even though the positive loop will reduce the variables' stability.

In general, the new model adjusts the new demand trend earlier and amplification and oscillation are reduced. Figures 8 and 9.

The values considered for the parameters are:

LT=1 day, TAI= 0.5 days. (Figure 8).

LT=1 day, TAI= 1 day . (Figure 9).

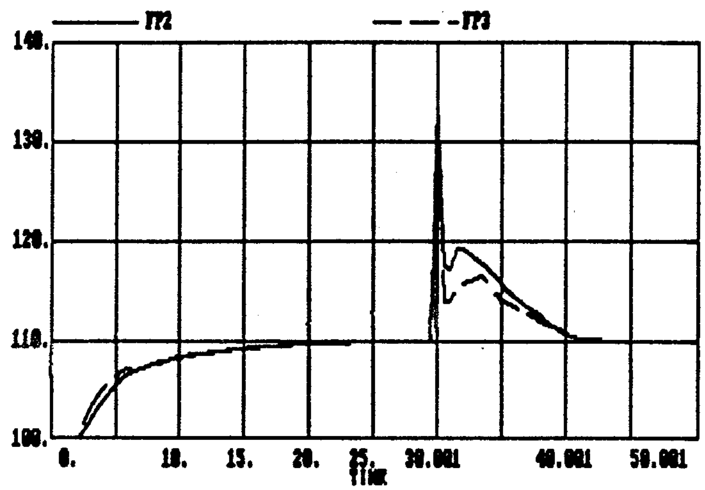

Figure. 8. Base stock model simulation.

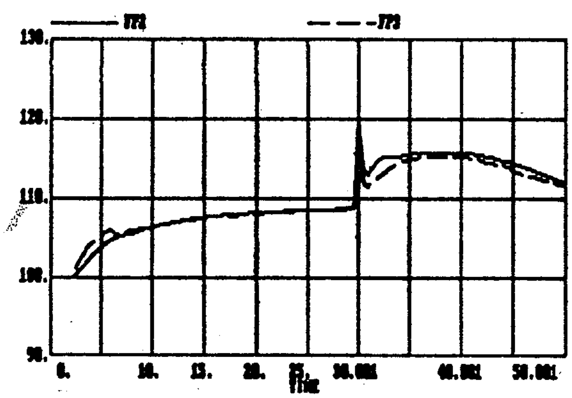

Figure. 9. Base stock model simulation.

4.- AN MRP MODEL.

The production management through an MRP program is a sample of a push manufacturing technique. A master production schedule (PP- Production Plan) is obtained from the demand forecast also taking into account the existing desired delivery rate. The model allows the option of changing the MRP planning period.

For a complete understanding of the model, figure 10 shows the global influence diagram where the process of calculating net requirements is depicted.

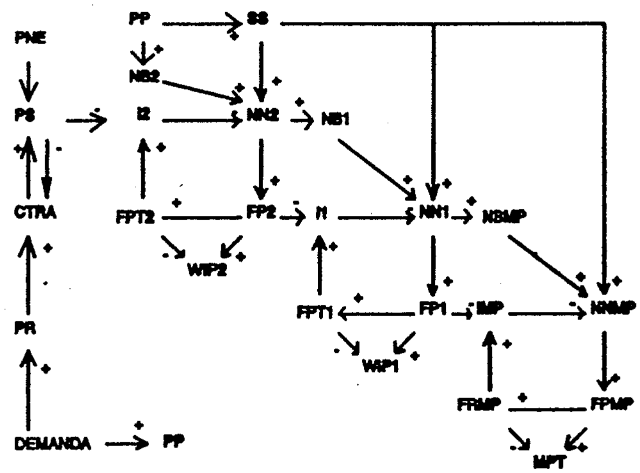

Figure. 10. Influence diagram. Three stages MRP model.

PP	=	Production Plan or MPS	FPi	=	Production rates
FPTi	=	Rate of product completed.	NNi	=	Net requirements.
NBi	=	Gross requirements.	WIPi	=	Work in process.
PS	=	Shipment rate.	CTRA	=	Orders backlog.
i	=	stage's index			

A negative feedback loop in every stage will be positive for the purpose of the system (figure 11). It's a fourth order delay loop, with a total delay of LT2+TAL.

In this model the inputs are relevant. The net requirements of every stage are the gross requirements of the precedent stage, but with no delay with respect to the master production schedule. Inventory discrepancies produced in the final manufacturing stages may lead to instability in the initial stages, as a result of the gain introduced in the aggregate production plan calculations. Several production rates for different production parameters are shown in the following figures.

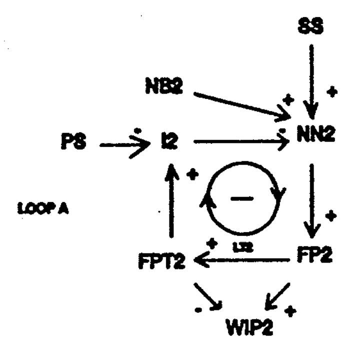

Figure. 11. Negative feedback loop in the MRP model.

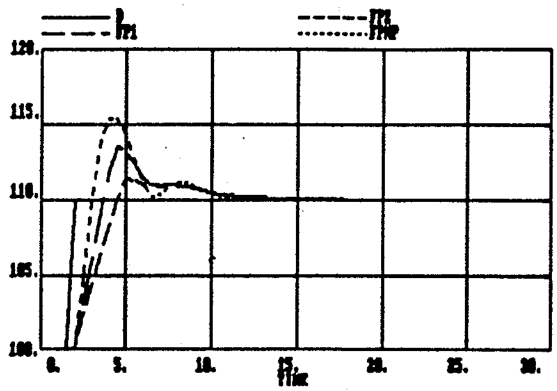

Figure. 12. MRP model simulation. LTi=.5 d., TAI=1.

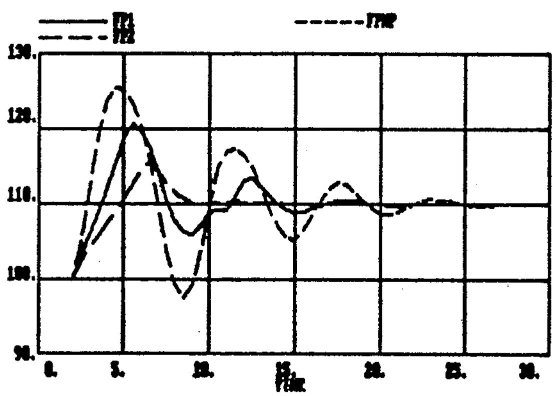

Figure. 13. MRP model simulation. LTi=1 d., TAI=1 d.

5.- A JIT-KANBAN MODEL.

In a KANBAN system pull & push effects are mixed. In these kind of system, there is no production until the final stages inventories are depleted; an obvious pull procedure.

On the other hand, and according to the master production schedule, the number of KANBANS for every stage of the system is checked periodically, and changed if necessary, trying to adjust production rates to demand earlier . This procedure is a manufacturing push mechanism. Figure 14 shows an influence diagram of a production stage in a KANBAN managed manufacturing process.

Three feedback loops identified in the influence diagram are shown in the following figures. Where:

NKi = number of KANBANS
PP = Production Plan
SS = Safety stock
ITi = KANBAN cicle
UCi = Units per container

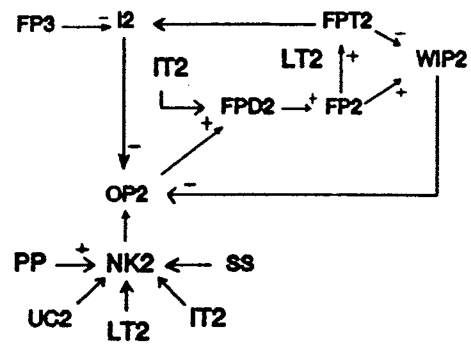

Figure. 14. Influence diagram of a production stage in a JIT-KANBAN model.

In figures 15,16 and 17 the three feedback loops of the KANBAN model influence diagram are shown. The performance of these loops is similar to that described for the base stock model, but a different input in the loops is introduced. The production orders (OP2),(O'Callaghan, 86):

OP.K=NK.K-WIP.K-I.K

introduce an input which is not delayed from the production plan.

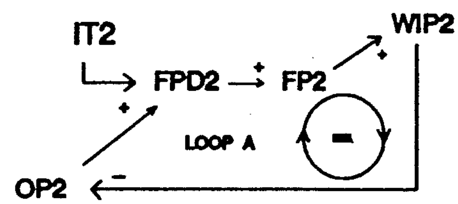

Figure. 15. First negative feedback loop in the KANBAN model.

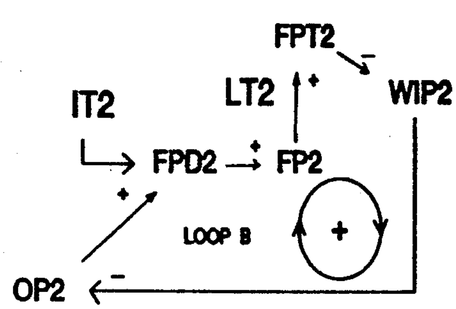

Figure. 16. Positive feedback loop in the KANBAN model.

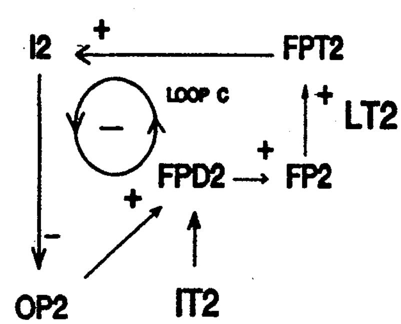

Figure. 17. Second negative feedback loop in the KANBAN model.

In the base stock model, the base stock was calculated, considering the demand of the next production stage, and therefore, an information delay was generated. The KANBAN model adjusts the demand signal earlier and with less oscillation. An example of this behaviour is shown in figure 18 where a safety stock factor (SS=0.4) is introduced in KANBAN'S calculations:

NKi.K=PP.K/UCi(LTi+ITi)(1+SS).

The effects of the planning period for the kanban system can also be seen in figure 19.

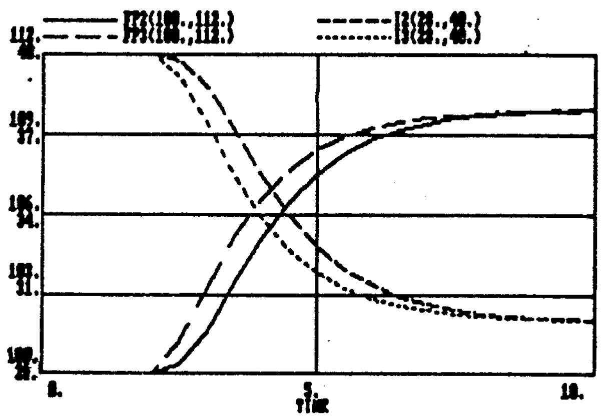

Figure. 18. JIT-KANBAN model simulation.
LTi=0.5 d. ITi=0,5 d.

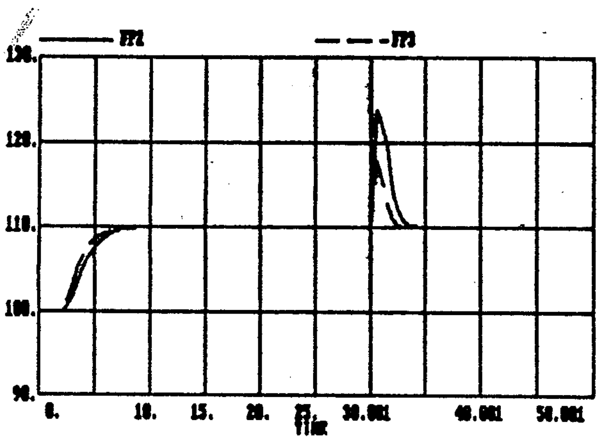

Figure. 19. JIT-KANBAN simulation. LTi=0.5.d, ITi=0.5 d., plannig period=30 d.

6.- CONCLUSIONS

A first evolution in the production techniques was focused on the change of the information structure, trying to consider, in the decision making processes all types of manufacturing inventories being placed in the different production stages. This is the most important difference between the order point and the base stock model policies. This actuation leads to lower oscillation, and therefore, lower amplification than that produced by the feedback loop's gain.

A second step ahead was to adjust the delay in the input of the system/existing demand, shortening the period of time in which system production stages could remain unaffected by external variations of demand. This effect was introduced according to the lead times of the production processes and was the initial contribution done by the MRP technique. It was also developed later in the kanban technique which could control this effect through its simplicify in field operations more easily.

Finally, KANBAN technique is a combination of both depicted effects. Structure, inputs and delays are coordinated through a hybrid approach. The result is a system based on high flexibility which responds faster to variations in demand with lower oscillation and amplification.

7.- REFERENCES

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