# GENERIC MODELS FOR EXPLANATION OF COMPLEX PRODUCTION SYSTEM DYNAMICS

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## ABSTRACT

This paper presents one middle term simulation model and its main results. We chose the production systems which produce complex capital goods, for example electrical equipement or household goods. The objective of this type of system is to build up stocks of finished goods which are put at the disposal of the customers. The corresponding macromodel was designed by a systemic vision and split into three components which represent the operating, decision and information production sub-systems. The simulation of the generic model has permitted the improvement of system dynamics knowledge. We detected prominent decision loops and some unnecessary loops in production control.

## THE PROBLEM

In production area, many computer programs are generally based on discrete events (see Bel and Dubois (1985)). These simulation concepts can be used with the purpose of forecasting and evaluating production systems evolution and results. As a matter of fact, problems with a limited scale or scope, can be solved successfully by using that approach. For example, discrete events simulation models can be well used to help design or management of shop floors.
However, when decision-makers need a more macroscopic approach, in case of large scale projects (designing or managing a complete factory for example), unfortunately discrete events simulation implies to built too complex models. As showed before, this class of simulation can not work properly without a detailed description of system behavior, that is incompatible with a global point of view (see also Forrester (1969), Howard, Krasnow and Merikallio (1964)).

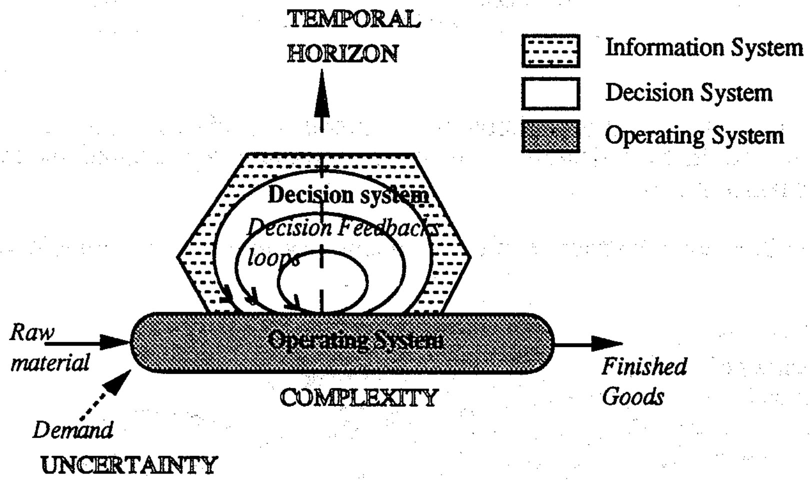
That is why we applied system dynamics paradigm and working on industrial problems, essentially to improve the knowledge of production system behaviors in cases of dysfunctions caused by internal and external hazards. In that perspective, we builded continuous generic models that describe particular sub-systems or sub-functions which are based on a classification of production systems and production problems.

The hypotheses follow an initial spadework and results of an pre-inquiry by interviews in industrial companies. These verifiable and specific hypotheses were striving to establish complex and abstract interrelations between system production variables.

## 1. CONCEPTUAL SCHEMA OF THE PRODUCTION SYSTEM

For the time being, we assume that it is possible to describe industrial phenomena with continuous models, eventually completed by discrete events models, if necessary. In this case, a main continuous model will take into account exogeneous variables issued from other discrete models during the simulation.
In accordance with the classical concepts of the system theory, we propose a basic schema of a production system (see figure 1).

Figure 1. Basic schema of production systems




This schema shows the three main sub-systems of any complex system: operating, decisional and informational. It shows also the three dimensions retained in order to characterize the production systems: customers demand uncertainty, complexity of products and production processes (see the production system typology proposed by Kieffer (1986)), and temporal horizon of decisions. In the figure 1, the decision feedback loops can also be represented at various hierarchical decision levels(2).

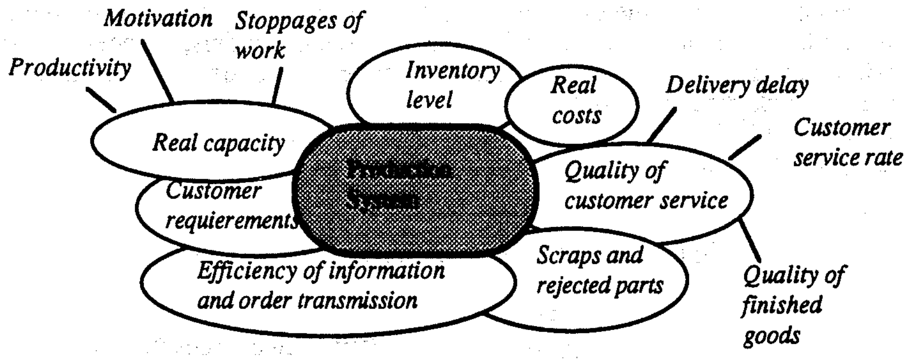
This systemic schema is the nodal point of our paper, because we developped simulation models resulting from the assembly of elementary submodels.

The formalisation of eight basic cybernetic loops and the designing of the operating system types have contributed to elaborate a cinematic production system description (Kieffer J-P.and Thiel D.(1992) and Thiel (1993a)).

## 2. BASIC CYBERNETIC DECISION LOOPS

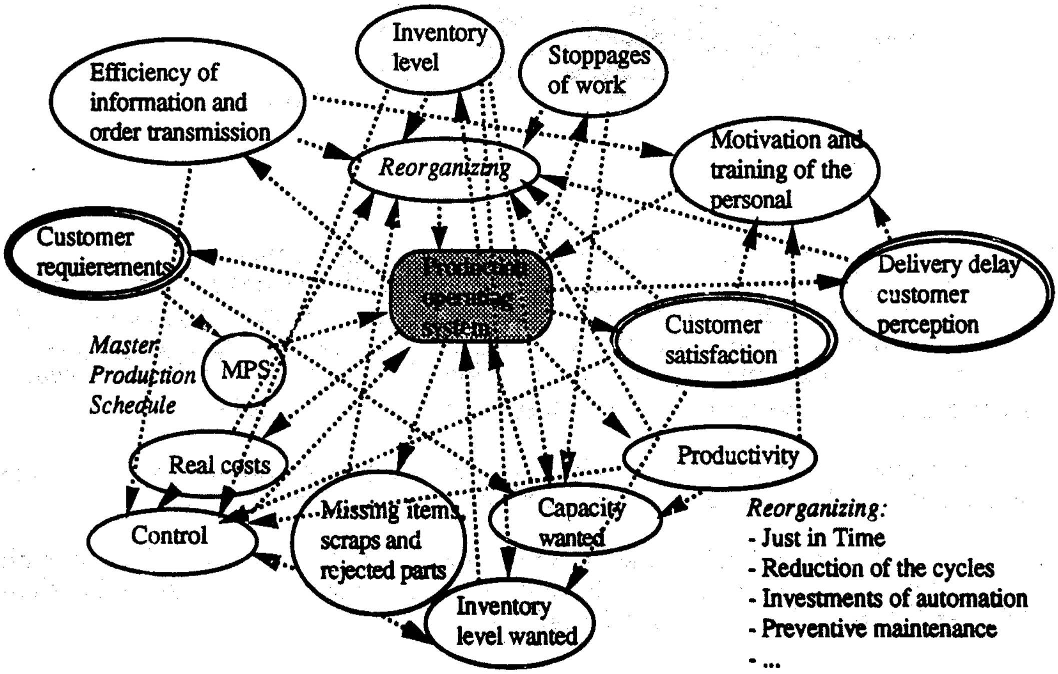
From the survey mentioned above, we extract some sensitive activity control indicators. The most sensitive are shown in figure 2. These indicators were given by the production managers as very important points to supervise or to take into consideration.

Figure 2. Major control indicators of the production systems



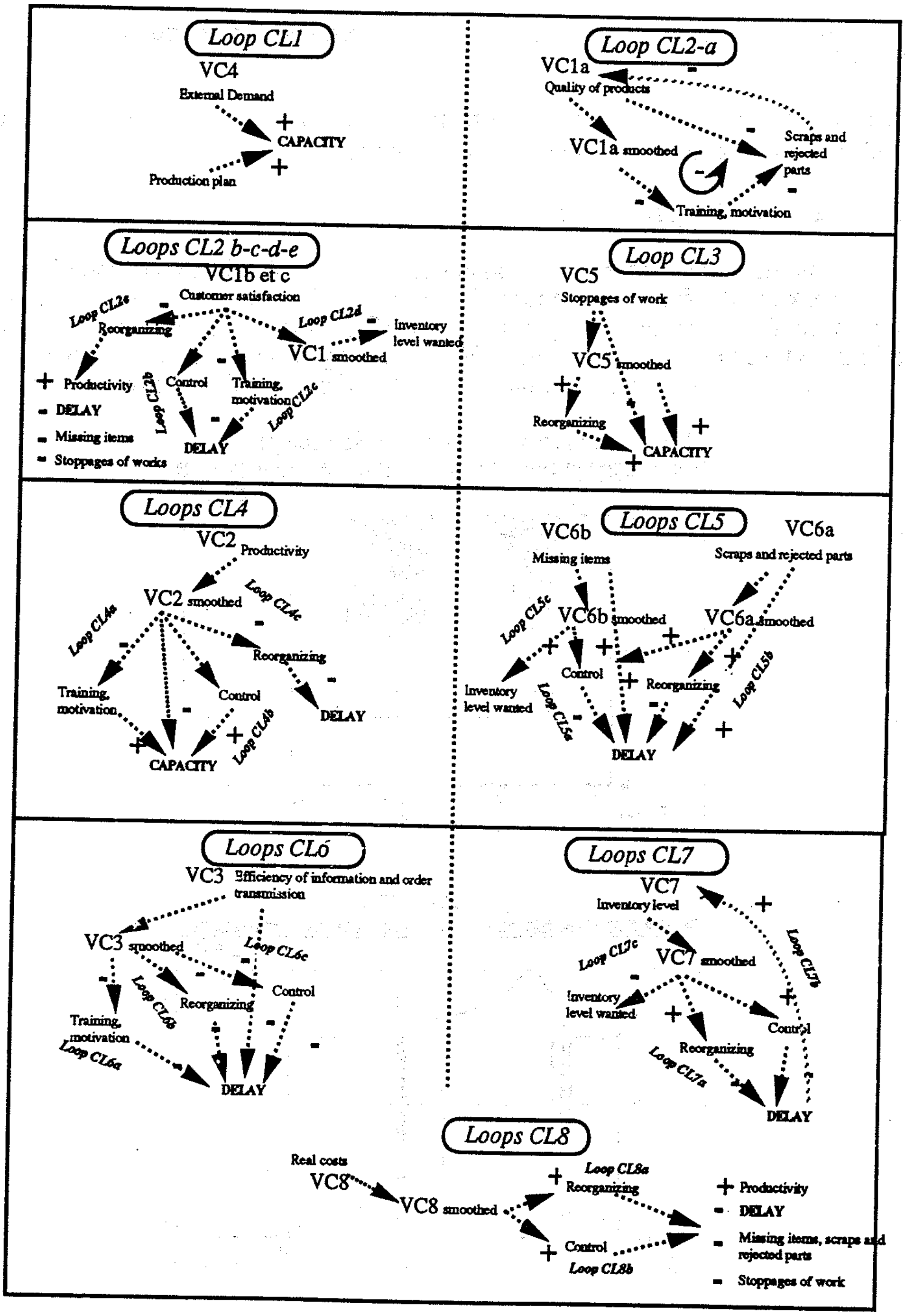

Our study brought out the decision mechanisms associated with each of these indicators. We could then design the feedback structure represented by cybernetic decision mechanisms in figure 3.

Figure 3. Feedback structure of the production system model in middle term




The figure 4 presents the different feedback loops in the generic model.

## FIG 4 Schema of feedback loops in middle term



## 3. RESULTS OF SIMULATIONS

### 3.1. Model behaviors in low (scenario 1), high (scenario 2) and medium (scenario 3) disturbed regimes

We study the sensitivity of the model to simultaneous perturbations of all the control variables, according to the hypothesis of our experience plan(3) .

· *Scenario 1 with low perturbations*

We note an increasing of the VA5 production capacity at the time t =15 months (see fig. 5). This peak results from the reaction faced with a VC1 customer satisfaction rate of 96% (see fig. 6). A progressive decrease in the VA5 capacity follows and then, there is drop in the VC1 rate on the 45th month. We observe again a new increase in the capacity. The production delays oscillate in a range of +/- 2% around their average (see fig. 7).

Fig. 5 Scenario 1: Customer Service(t)

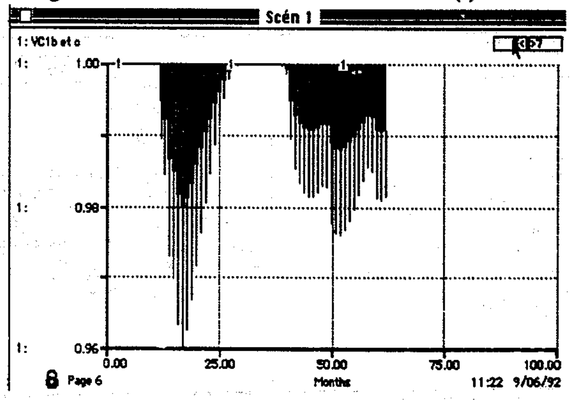



Fig. 6 Capacity(t)

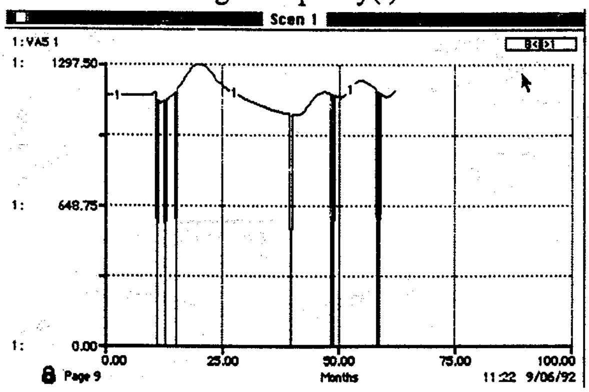
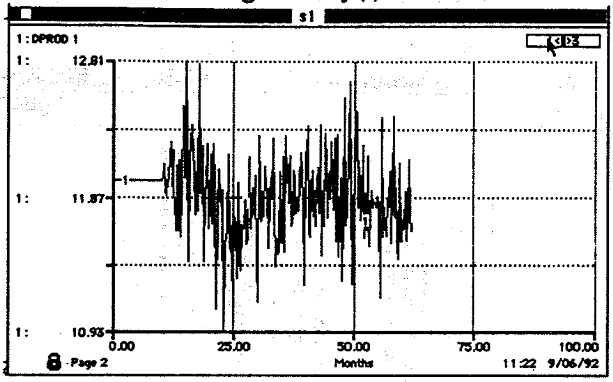


Fig.7 Delay(t)




· ***Scenario 2 with high perturbations***

In this most unlikely scenario, the model is not able to improve enough his customer service quality (see fig. 8), in spite of the doubling of his VA5 capacity (fig. 9).

Fig. 8 Scenario 2: Service(t)

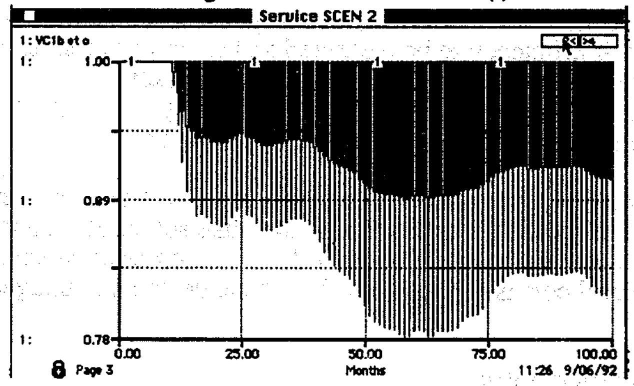
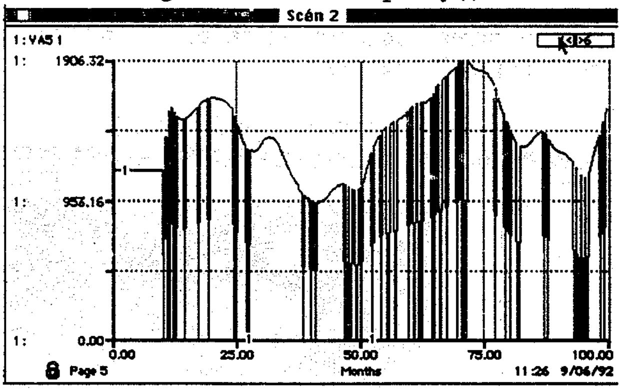


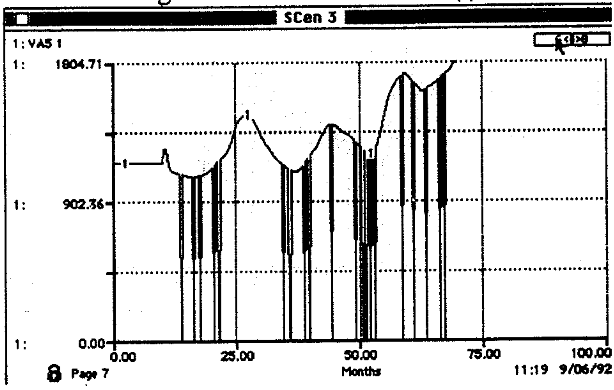

Fig. 9 Scenario 2: Capacity(t)




· ***Scenario 3 with medium perturbations***

In this scenario, the model **is efficient and** can progessively improve the service quality VC1 (fig. 10) by increasing the capacity VA5.

Fig. 10 Scénario 3: Service(t)




### 3.2. Sensitive analysis of different regulation loops

A study of the sensitivity of decision mechanisms to the essential control variables, has enabled a control of individual efficiency of every loop. The inhibition of some of them, has also enabled their efficiency to be measured and an explanation of their global system behavior to be given. Every loop has been studyed separately.

In this production system which produces complex capital goods, the loop CL2d (see fig. 4) is prominent. It defines a new inventory level after a decrease in the customer quality service.

In case of information and order transmission rate VC3 greater then 70%, the loops CL6 which control this variable, is prominent and take action of production delays.

We observed also that the coupled loops CL8 are unneccessary when the cost ratio VC8 equals 1.4 (i.e. the real cost is 40% greater then the expected and budgeted cost).

### 3.3. Sudden changes in sales

· ***Positive step***

In case of a sudden 10% increase in sales, the capacities and the delays progress over 41 months as shown in figures 11, 12 and 13.

Fig. 11 Positive step: Service(t)

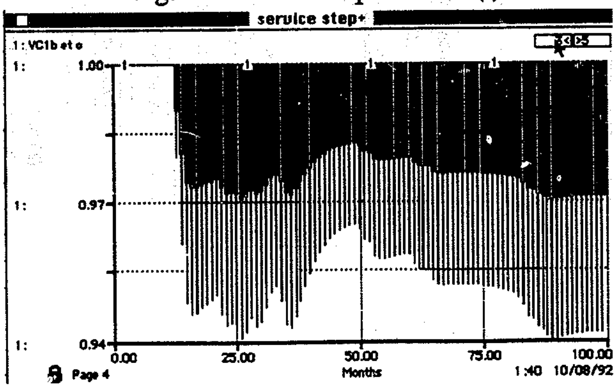


Fig. 12 Positive step: Delay(t)

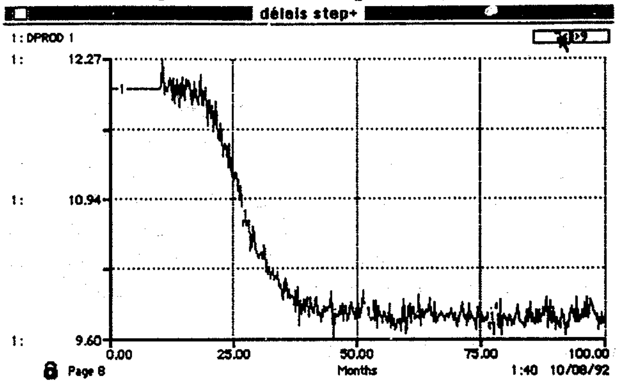
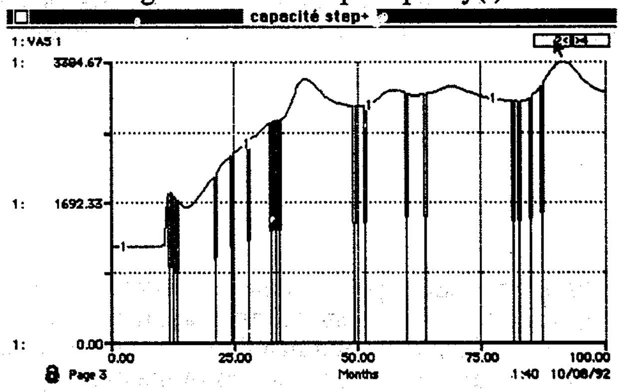



Fig. 13 Positive step: Capacity(t)




## 4. ANALYSIS OF BEHAVIORS

This paragraph presents the essential results of our cognitive research. This work consisted in observation of the reality by means of interviews and surveys, to analyse and to interpret the simulation results, and finally, to generalize production system behaviors.

We expose here only the most inusual behaviors(4) of these systems which produce complex capital goods, for example electrical equipement or household goods. In this type of system, if there is an increase in missing items, scraps and rejected parts, it acts essentially on the production lot sizing to increase its stocks. It is not necessary in these factories, to reinforce direct personal control.

We also observe that these systems are very sensitive to their production indicator variations (described by fig. 2). The simulation results emphasize the large difficulties of these systems confronted with important dysfunctions (based of scenario 2).

### 4.1. Linkage phenomena between regulation loops

In some circumstances, in order to assume a global efficiency, we noted the necessity to link different control mechanisms. The opposite was also true because we observed a decrease of the customer service rate in simultaneous presence of some linked loops.

In this type of production system, it is always necessary to associate the three loops CL6 (see fig. 4) to assumme the regulatution in case of difficulty in transmitting information and orders.

We also observed that when the cost increased, a direct shopfloor control is not useful to improve delays (to reduce the pipeline inventory level) and productivity. A soon as the real costs exceed 40% of the standard costs (pessimistic, but realistic), the direct linked mechanisms are not so useful, because other regulation loops operate a correct customer service level. Nevertheless, the absence of one of the components of this loop association, caused a 10% drop in customer service rate. It can be explained by an unbalance caused by the separation of one regulation loop of this linkage.

### 4.2. Influence of the capacity modification delay

Delays to modify the production capacity are taken into account in our model. They set back a desired capacity modification by third-order exponential delay. We note that the production system which build up stocks of finished goods, are hardly sensitive to this type of delay.

## CONCLUSION

The main results observed in this type of production system were that if there were an increase in work stoppages, the corresponding regulation loop would be inactive however an other control mechanism would function. We also detected prominent loops, for example the loop which controlled the variations of the missing items, the scraps and rejected parts rates. Other observations permitted us to improve the knowledge of non-linear mechanisms in complex production systems.

In conclusion, these observations permit us to open a field of application towards production control system engineering. We recently tested in one of the factories we initially analysed, our simulation results to improve their industrial dynamics behaviors. As shown in our previous communications (see Thiel (1990) and (1993b)), we make some comparisons with real results obtained in an industrial context by means of our previous engineering works.

### Notes

(1) see Simon (1960), Antony (1965), Gorry G.A. and Scott Morton (1971), Le Moigne (1974 and 1977).

(2) according to Antony (1965)

(3) we developped the model with Stella software, HPS (1990), written by V. Kerchner, K. Richm Ond and J. Gäss.

(4) J.W. Forrester called them «anti-intuitive» behaviors.

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