# A COMPETITIVE INTELLIGENCE SYSTEM FOR TOTAL QUALITY MANUFACTURING STRATEGIES

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## ABSTRACT

The function of a competitive intelligence system is to generate a manufacturing strategy which is superior than the competition. A competitive intelligence system consists of a set of tools that capture and synthesize the competitors manufacturing strategies in order to generate the desired strategy. A competitive intelligence system that uses reference models is presented here and its use illustrated with a case study. A reference model is a generic system dynamics model which includes the cause-effect relationships that explain the current quality of the competitors products.

## INTRODUCTION

All products exhibit design characteristics and managerial characteristics. The design characteristics are defined by the structure of the product while the managerial characteristics are inherited by the product from the manufacturing system. The product managerial characteristics desired by the customers are "zero" delivery delay, "zero" defectives, "zero" overhead cost and "large" variety (Hayes, 1988). In practice the product design characteristics are well known and are specified as a set of norms. Usually the product managerial characteristics are not as desired by the customer.

This paper assumes that the product design characteristics completely satisfy the customer so that a deep reconception of the product structure or the manufacturing process is unnecessary. It is also assumed that the product managerial characteristics do not satisfy the customer so that the current organization of the manufacturing system must be improved.

A total quality manufacturing (TQM) strategy is a set of improvements in the organization of a manufacturing system in order to obtain products with the desired managerial characteristics. The basic method for conceiving a TQM strategy is illustrated in figure 1. As indicated, the conception process begins when the product managerial characteristics differ from the desired

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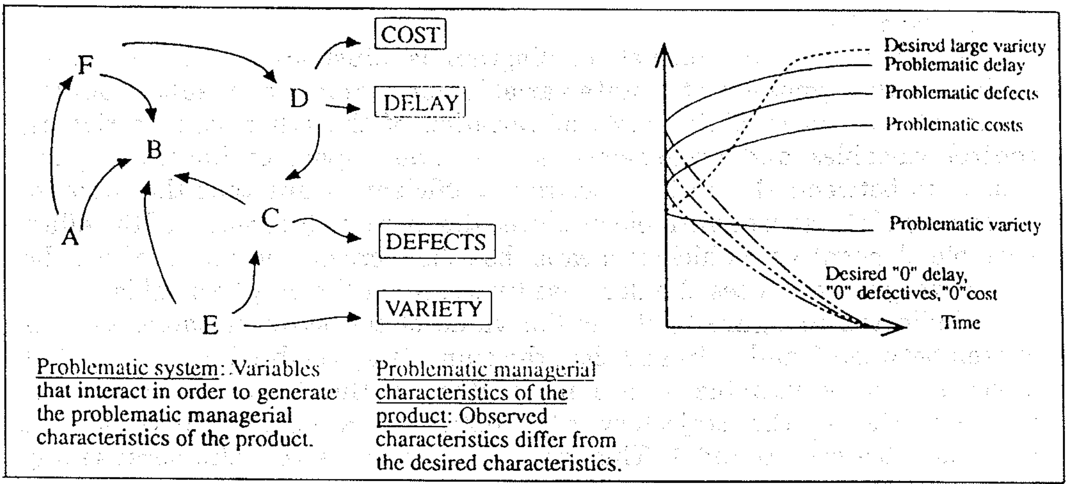


Figure 1. The conception of a manufacturing strategy: The problematic managerial characteristics of the product are decomposed in order to identify the problematic system. Next, the controllable components of the problematic system that will reduce the gap between the problematic and the desired values of the product managerial characteristics are identified. Finally, the values of these controllable components are specified. The controllable components and their values constitute the manufacturing strategy.

ones. In this case the question "Why?" is repetitively asked until the true sources of the observed managerial characteristic are identified. In this way a problematic system is identified. The variables included in the problematic system belong to the organization of the manufacturing system, particularly to the product structure (the "what"), the production flow (the "where"), the set-up operations (the "how"), the human factor (the "who") and the production planning (the "when"), as indicated elsewhere (Macedo, 1991).

A competitive intelligence system is the set of tools to capture and synthesize the competitors TQM strategies in order to produce a more effective TQM strategy (Fuld, 1988). Current competitive intelligence systems lack tools for linking competitors data and for synthesizing the competitors TQM strategies (Prescott, 1989). The goal of this paper is to present a competitive intelligence system implemented as an expert system that utilizes reference models and their strategies (named reference strategies). The reference models allow to link data from various competitors while the reference strategies are the synthesis of the competitors TQM strategies. Using model recognition the expert system inference engine determines when an available reference strategy can be used for a particular problematic system.

## CAUSE-EFFECT DIAGRAM

The models used by the competitive system are built using cause-effect diagrams which are transformed to level-rate models and finally to differential equations which are solved by simulation using the language DYNAMO

(Richardson, 1981).

The structure of a cause-effect diagram is illustrated in figure 2. As indicated, the dynamics of a state variable, for example $x_i$, results from the weighted influences of the rates of variation of the other state variables, control variables and exogeneous factors. The impact coefficients $w_i$ are constants between -1 and 1. A positive coefficient means that the increase (decrease) of the source variable produces the increase (decrease) of the effect variable. A negative coefficient means that the increase (decrease) of the the source variable produces the decrease (increase) of the effect variable.

As indicated in figure 2, the initial value of the state variable, $x_i(0)$, is chosen between 0 and 1. In addition, the sum of the weighted influences that affect the state variable $x_i$ are modulated by the "peruvian mountain" function. Hence, the trajectory $x_i(t)$, $0 \le t \le T$, is a logistic curve always comprised between 0 and 1. This kind of trajectory is realistic because any state variable cannot grow undefinitely.

The "peruvian mountain" function is the derivative of a logistic function and can be easily programmed as a tabular function in DYNAMO. The nonlinearity of this function clusters the dynamics of the state variables in regions which are structurally different. Hence, some values of the control variables can produce structural changes that allow to reach the region where the desired managerial characteristics are satisfied. These critical values form the sought after TQM strategy.

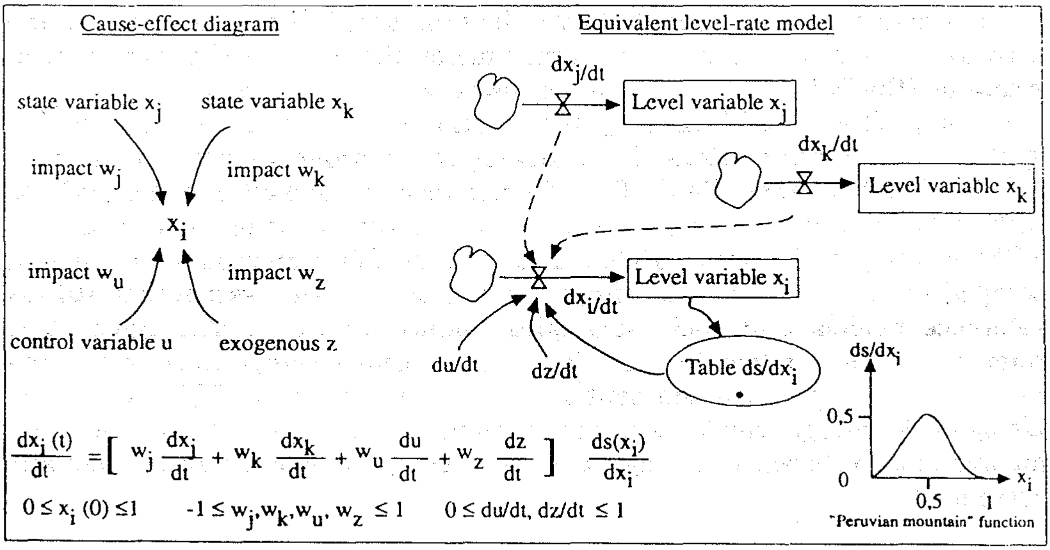


Figure 2. The structure of a cause-effect diagram is represented on the left side of the figure while its corresponding level rate model is on the right side. The cause-effect diagram is constituted by rates of variations of state (level ) variables, control variables and exogeneous. Note that an impact coefficient represents the positive or negative influence of the rate of variation of one variable on the rate of variation of another variable.

## THE COMPETITIVE INTELLIGENCE SYSTEM

The competitive intelligence system uses two kinds of models, problematic models and reference models. A problematic model is a cause-effect diagram obtained by decomposing the problematic managerial characteristics of the product as indicated in figure 1. Any problematic model is obtained by analyzing an specific firm.

The problematic models obtained by analyzing the industrial firms can be grouped in clusters. Each cluster is formed by the problematic models that include common variables but different impact weights that can vary within some intervals. Each cluster can be replaced by a generic problematic model named reference model (Macedo, 1993). A reference model with specific impact weights and control variables becomes a problematic model.

In practice, most of the reference models are formed by the same organizational variables and cause-effect relationships. These models differ only on the values of their impact coefficients (Macedo, 1993). For example, in a manual assembly line the variable "micromovement economy" has a strong negative influence on the variable "time to execute the operation". On the other hand in an automated beer fill up line the impact coefficient of the cause-effect of these two variables is weak.

The competitive intelligence system implemented as an expert system is illustrated in figure 3. It consists of building a problematic model and then

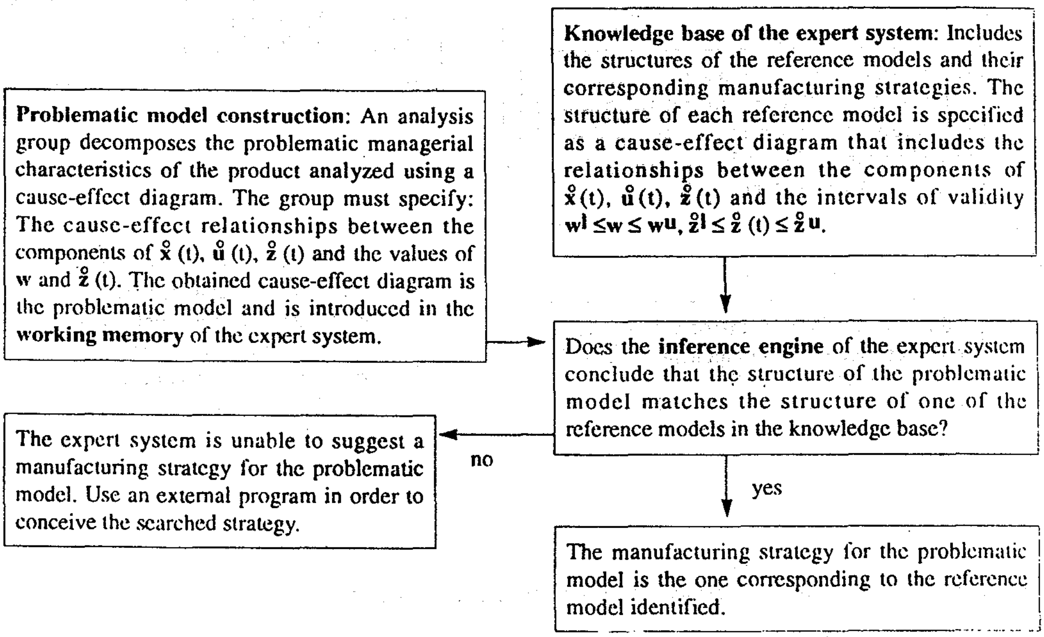


Figure 3. Procedure used by the expert system in order to identify the manufacturing strategy of a problematic model.

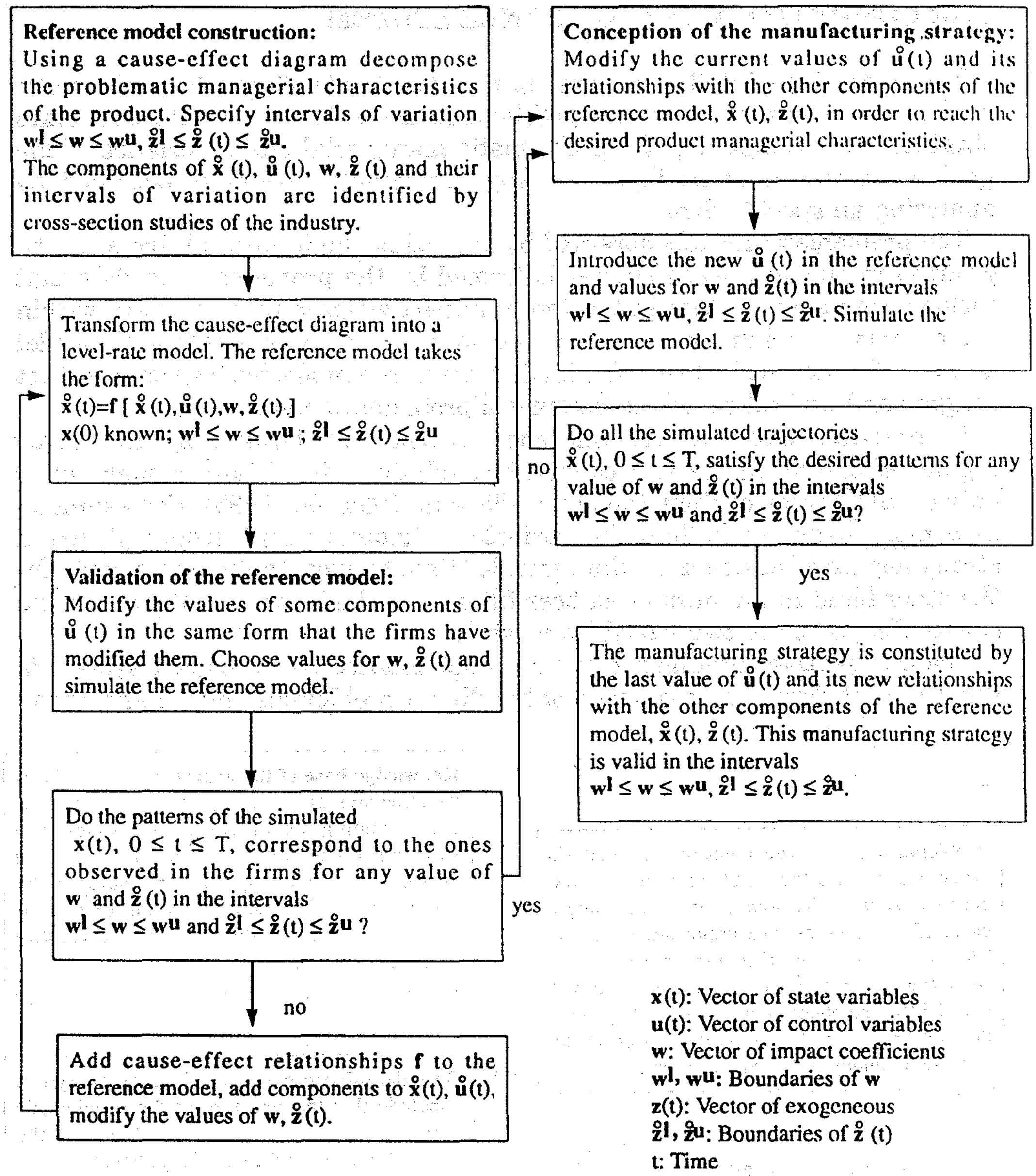


Figure 4. Construction of the reference model and conception of its strategy.

**comparing its structure to the structures of the available reference models. The strategy of the reference model that matches the problematic model is selected for this latter. The matching happens when the problematic model**

relationships are identical to the ones of the reference model and the problematic model impact coefficients are within the intervals allowed by the reference model. When no matching is possible the TQM strategy must be obtained by simulating the problematic model.

The construction of the reference model and the conception of its strategy are illustrated in figure 4. The validation step consists of modifying the model control variables in the same form that the managers did in the real world and by simulating the model. The simulated dynamics must correspond to the improved dynamics observed in the reality. The conception of the TQM reference strategy consists of identifying the values of the control variables that exhibit the highest leverage for reaching the desired managerial characteristics. This strategy must be robust to small variations of the impact coefficients and of the values of the exogeneous factors in the intervals allowed by the reference model.

## A CASE STUDY

Twenty five manufacturing firms that make products with low delivery delays and low number of defective products were selected in order to build a set of reference models. In order to reduce the time required for developing these models the state variables included in the reference models were limited to the human factor (Macedo, 1991).

Each plant was visited and its operations managers interviewed in order to build a problematic model that explains the current values of the delivery delay and the number of defectives. Next, the problematic models that show common cause-effect relationships and impact coefficients in some intervals were utilized to build a reference model. The mentionned intervals were progressively defined by identifying the values of the impact coefficients so that the patterns of the delivery delay and the number of defectives did not change during the simulations of the problematic models.

In this way a set of reference models were built and stored in the knowledge base of the expert system named VP-EXPERT as explained elsewhere (Macedo and Ruiz Usano, 1993). One of these reference models is shown in figure 5, the logic of its cause-effect relationships can be explained in the following form.

When the orderliness, the lack of warning signals and the broken tools increase, the operator displacements increase so that the time to execute the operations grows thus increasing the manufacturing delay. This result is accentuated when the number of managers that approve the work orders is high or when more than one manager defines the operator task. On the other hand, the microvement economy reduces the time to execute the operations and finally the manufacturing delay. However, the microvement economy reduces the motivation of the worker that produces more defective products resulting in an increase of the manufacturing delay.

As indicated in figure 5, the maintenance of the machines, the use of visible working procedures, the use of ergonomic work stations and the search of solutions in group increases the workers motivation. In addition, the use of unexpensive inspection mechanisms that guarantee zero defectives and the reduction of the delay necessary for identifying and correcting the defective products, diminishes the number of defective products and ultimately the

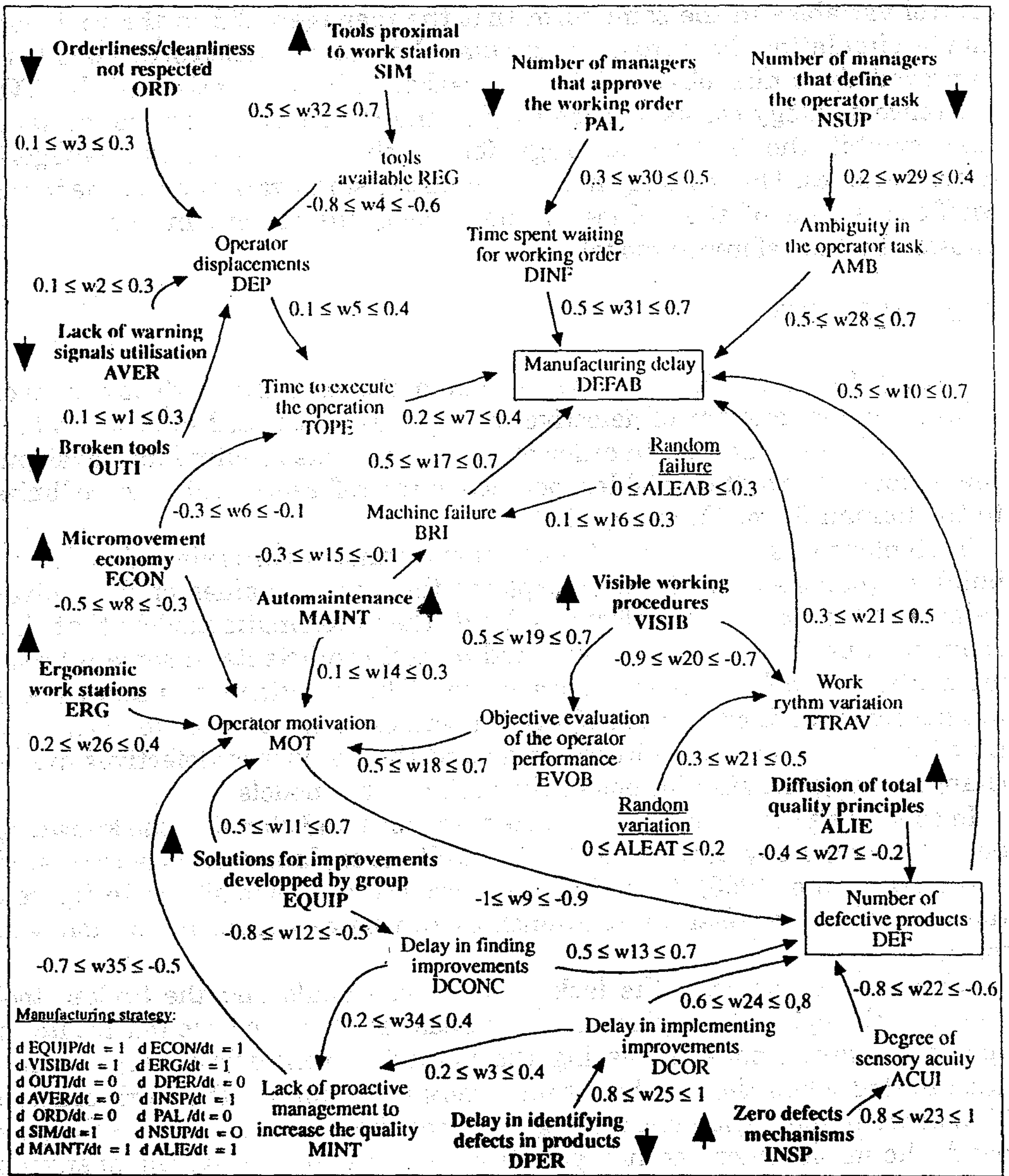


Figure 5. Reference model limited to the human factor. All the names included are state variables, with the exception of the names in bold characters which are control variables and the underlined names which are exogeneous. The manufacturing strategy is constituted by maximum increase ▲ or decrease ▼ in the rates of variation of the indicated control variables. The variables in the boxes are the problematic managerial characteristics of the product.

manufacturing delay. This result is accentuated by the reduction of the delay necessary to identify and correct the defective products.

Once the reference model of figure 5 was validated, its strategy was found by following the procedure of the right side of figure 4. The resultant TQM strategy consists of increasing or decreasing the rates of variation of the control variables as indicated in figure 5. This reference strategy reduced the current delivery delay and the number of defectives more than any observed competitor strategy.

In order to validate the suggested competitive intelligence system a small furniture manufacturer with high delivery delay and high number of defectives (with respect to the competitors) was chosen. Next, a problematic model limited to the human factor was built by following the procedure indicated in the left side of figure 3. Finally this problematic model was introduced in the working memory of the expert system that contained in its knowledge base a set of reference models. The inference engine of the expert system concluded that the problematic model under analysis matches the reference model of figure 5. Hence, the expert system suggested for the problematic model the reference strategy indicated in figure 5.

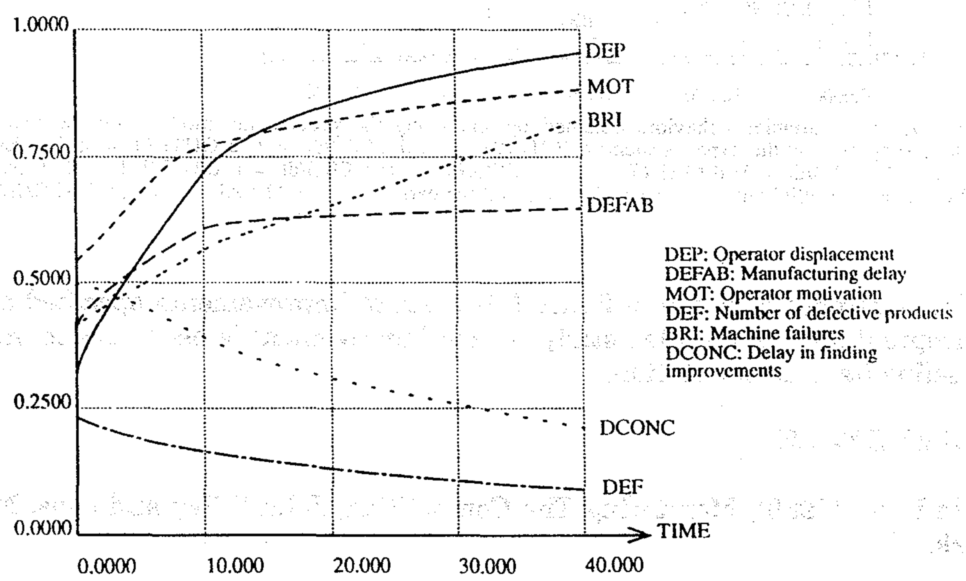


Figure 6. State variables behaviors obtained by simulating the problematic model with the current values of the rates of variation of the control variables : d EQUIP/dt = 0.05; d VISIB/dt = 0.2; d OUTI/dt = 0.2; d AVER/dt = 0.2; d ORD/dt = 0.2; d SIM/dt = 0.05; d MAINT/dt = 0.1; d ECON/dt = 0.1; d ERG/dt = 0.1; d DPER/dt = 0.3; d INSP/dt = 0.1; d PAL/dt = 0.6; d NSUP/dt = 0.6; d ALIE/dt = 0.05 and the exogeneous d ALEAB/dt = 0.3; d ALEAT/dt = 0.2.

The simulation of the furniture manufacturer problematic model with its current TQM strategy produces the dynamics of figure 6. As noted, the manufacturing delay and the number of defectives are high. On the other hand, the new dynamics obtained by simulating the problematic model with the reference strategy suggested by the expert system are shown in figure 7. As noted, the manufacturing delay and the number of defectives have dramatically decreased.

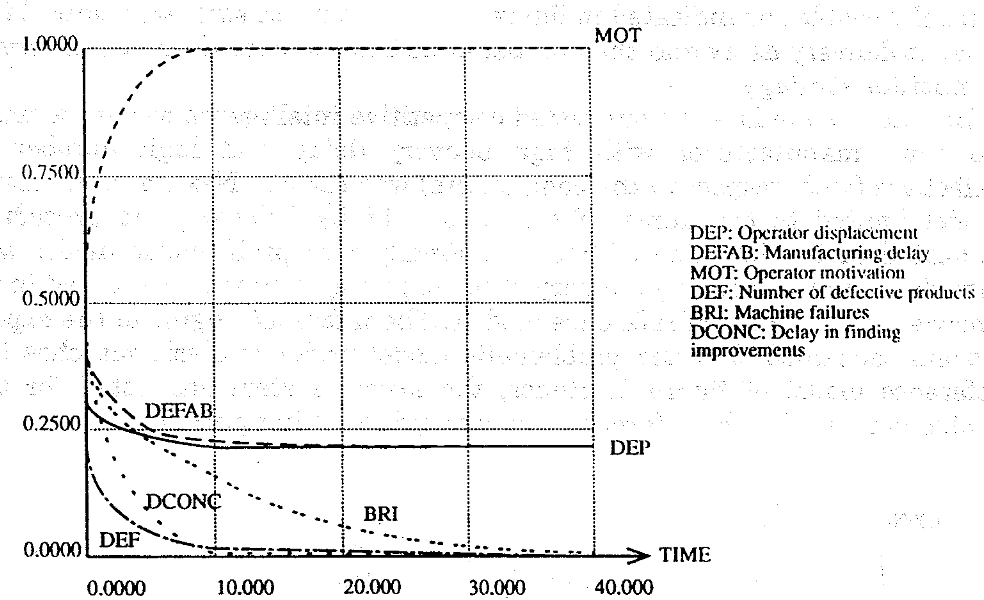


Figure 7. State variables behaviors obtained by simulating the problematic model with the manufacturing strategy suggested by the expert system: d EQUIP/dt = 1; d VISIB/dt = 1; d OUTI /dt = 0; d AVER/dt = 0; d ORD = 0; d SIM/dt = 1; d MAINT/dt = 1; d ECON/dt = 1; d ERG/dt = 1; d DPER/dt = 0; d INSP/dt = 1; d PAL/dt = 0; d NSUP/dt = 0; d ALIE/dt = 1 and the exogeneous d ALEAB/dt = 0.3; d ALEAT/dt = 0.2.

The reference strategy of figure 5 is a set of improvements specified at a conceptual level. A detailed study of each improvement is necessary in order to define its implementation.

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