# A HYBRID DECISION SUPPORT SYSTEM

## *The joint use of Simulation, Coloured Petri Nets and Expert System*

Fabiano A. Hennemann, Ricardo J. Rabelo, José E. R. Cury
*DAS - UFSC, P O Box 476, 88040-900 – Florianópolis – SC, Brazil*

José V. Canto dos Santos, Arthur T. Gómez
*PIPCA – UNISINOS, P O Box 275, 93022-000 – São Leopoldo – RS, Brazil*

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Abstract: This works aim to propose a Hybrid Decision Support System (HDSS), based in Simulation and Coloured Petri Nets as modelling techniques of manufacture processes, and an Expert System to assist in its use. The HDSS provides a friendly interface for the user that, after selecting input parameters, gets a series of data about the manufacturing process that will assist in the evaluation of its performance as answer. To validate the proposal, some particular scenes have been tested, with the objective of elaborate a set of proposals for improving the performance of productive systems, evaluating the impacts from the change on model parameters and providing a better understanding about the systems considered. The HDSS makes possible for managers, without knowledge of modelling techniques, manipulate data and interact with the models. The developed prototype is generic for applying on general manufacturing processes, making it possible to use it for any industrial plant, since that the input parameters of the model are adequately fitted.

# 1 INTRODUCTION

The companies must constantly improve its manufacture processes and its methodologies of work. For this, becomes necessary the improvement of the productive process, looking for the reduction of lead times, costs of production, improvement of the quality, among others. However, this objective is very difficult to reach. One of the causes is the lack of good computational systems that assist managers in the evaluation of the company and the posterior decisions. The existence of a tool to support decision that interacts with a model of the manufacture process could benefit these companies to analyze the performance of its processes, to establish schedules of execution with precision, to relate the operations and to plan the resources necessary in the manufacture process of each product type. In literature, the development of systems based on some specific approaches is found, with its results presenting, of course, inherent limitations to the used techniques. This work presents a Hybrid Decision Support System that combines the potentialities of some excellent approaches, aiming at to improve the quality of the diagnosis and the decisions to be done. The techniques integrated in this work are Simulation, Coloured Petri Nets and Expert Systems.

In this work the shoes matrices production segment was chosen to evaluate and to validate the proposal. Its processes can be considered as flow shop type (Askin & Standridge, 1993), with great variability and average production, as described in (Groover, 2001). The research aims, in short, to study the productive processes in manufacture environments, with the objective to supply theoretical subsidies through tools and documentation, in order to assist administrative resolutions. The choice of modelling techniques, whose contributions interact with the processes managers, through a HDSS, as suggested in (Piesik & Weglarz, 1999) and (O'Reilly & Lilegdon, 1999) is a appropriate strategy in this context. The article is organized as follows: Section 2 presents the Identified Problems; Section 3 shows the proposed model and aspects related to the implementation; in Section 4 the results and the structural validation with CPNs are shown; and finally, Section 5 presents the conclusions.

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## 2 IDENTIFIED PROBLEMS

During the mapping of the process operations and in interviews made with managers of productive processes, some problems had been identified. These problems are listed below.

- The products manufacture sequence are frequently unregistered, making difficult the visualization, understanding and analysis of the process.;
- There are few estimates of necessary manufacture times. The stated periods are supplied to the customer based on the experience of the managers;
- Trustworthy estimative about the use of available resources does not exist;
- Absence of a tool to analyze impacts from investments in new resources;
- Extensive amount of rework.

## 3 PROPOSED SYSTEM

The structure of the proposed system is based on the problems that had been highlighted by the managers and in the possible results that each modelling technique can produce. The HDSS interacts directly with the simulation model developed with a Simulator. The use of CPNs complements the available data on the manufacture process and analyzes the properties of this model in structural terms, validating it. Because the simulator and the CPN generate an enormous amount of information, the manager is assisted by the module of intelligence, represented for an Expert System, who assists in the data interpretation. Figure 1 shows the basic architecture of the proposed system. Each part of the system is described below.

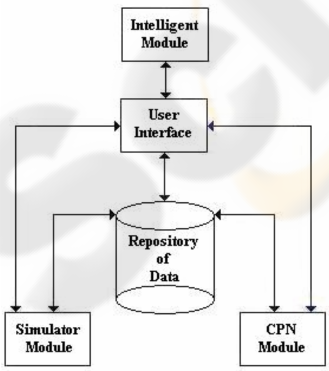


Figure 1: Basic architecture of the proposed system.

### 3.1 User Interface

This module is divided in two parts called: Managing Module - Data entry and Managing Module - Results. Using the User Interface, the manager selects and modifies the desired parameters, before executing the Simulation. After, these parameters are saved on text files in the Repository of Data and the Simulation begins. Concluded this stage, the results are shown to the user and stored again in the Repository. This module was developed using *Delphi* as programming language.

### 3.2 Expert System

The Expert System is divided in two modules. The first module assists in the definition of the data that must be selected in the User Interface - Data Entry and the second provides the interpretation of the Results, shown in the Managing Module. This function helps the manager in the interaction with the User Interface and interpretation of the Results that the HDSS presents. The Expert System was developed in shell *Expert Sinta*.

### 3.3 Repository of Data

This module stores all the information supplied in the User Interface Module, the results reached for Simulator and CPNs, and all the data used by the Simulator program. This repository also stores the set of logs from all evaluated scenes. Beyond serving for future evaluations, the objective of this base is to make possible that the different scenes of developed tests are compared, without necessity of a new simulation. The files are *MS Excel* spread sheets.

### 3.4 Simulator Module

With this module, through the selection of some parameters, the manager gets the following results: amount produced, daily production; WIP; graph with the state of the entities; graph with utilization and the state of the resources; graph of use and the state of the production stages; relation of the resources (humans and machines) that are being used in more than 60% of the time; measurers with permanence time in each sector and documentation with process data. This module was constructed with the software *Promodel*.

## 3.5 CPN Module

The CPN module was developed with top-down approach (Jensen, 1996). Figure 2 shows a small example of this net. The application of the CPN is justified because that the majority of the systems are complex, making traditional Petri Nets inadequate to represent a model with large dimensions. The deadlock property (Dicesare et alli, 1993) of the physical system is verified. The model was developed with software *CPN Tools*.

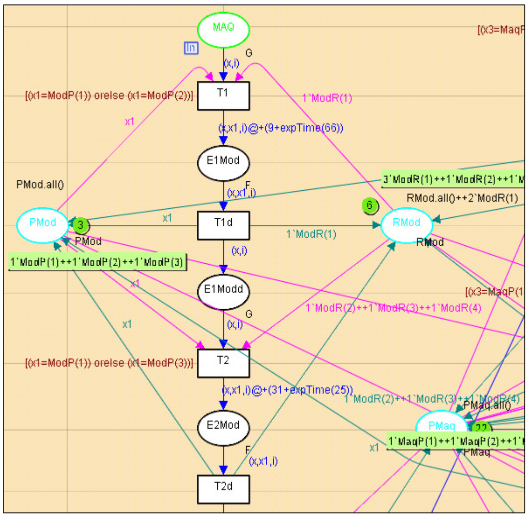


Figure 2: Part of a CPN model

## 4 RESULTS

Using the collected data of the current process, tests with HDSS has been carried through. The results of these tests for the production of matrices are presented in Table 1. The space limitation imposes the results shown of a one type of matrix (PUS). (The amount of results is extensive and related to several products.) Considering that the reached results represents the real behavior of the process, some pointers have been used to mark the elaboration of alternative scenes of improvements, focused in the reduction of production time and increase of productive capacity.

### 4.1 Scene 1

In Table 1 is shown the resources with the bigger percentage of use in the productive plant. Because the majority of these are human resources, more people training to execute the corresponding stages were suggested. For such, the resources indicated in Table 1 had been duplicates and the new results are presented in Table 2.

Table 1: Current scene

| PUS (Model) | |
|---|---|
| Amount Production | 32 |
| PUS/Day | 1,15 |
| WIP | 83 |
| Busiest Resources | P1Mod, P2Mod,P3Mod |
| Busiest Resources | P1Maq,P2Maq,P3Maq,P4Maq |
| In Operation | 59,25% |
| Blocked | 26,60% |
| Wait for Resources | 14,13% |

Table 2: Scene 1.

| PUS (Model) | |
|---|---|
| Amount Production | 50 |
| PUS/Day | 1,73 |
| WIP | 88 |
| Busiest Resources | P1Mod, P2Mod,P3Mod,R1Mod |
| Busiest Resources | R4Mod, P1Maq,P2Maq,P3Maq |
| Busiest Resources | P4Maq,P22Maq |
| In Operation | 60,77% |
| Blocked | 25,08% |
| Wait for Resources | 14,13% |

The most significant differences between the current scene and the scene 1 are listed below:

- Increase 56% productivity of matrices PUS;
- Machine resources appear with index of use above 60%;

It was concluded that scene 1 introduces improvements to the current scene, mainly in relation to the significant addition of production in the matrices.

### 4.2 Scene 2

Aiming improve the data found in scene 1, the changes shown in Table 3 will be carried through using the HDSS. These changes are based on the resources that had presented the biggest percentage of use. Comparing the results of this scene with the current scene, in Table 4, the following ones can be detached as main alterations:

- Increase of productivity of more than 100% of matrices of type PUS;
- The time of production product PUS falls significantly;
- The values of products in operation, blocked and waiting resources had remained essencially the same.

Table 3: Changes in Scene 1

| Previous Resources | Modified Resources |
|---|---|
| 1 P1Mod | 3 P1Mod |
| 1 P2Mod | 3 P2Mod |
| 1 P3Mod | 3 P3Mod |
| 1 P1Maq | 3 P1Maq |
| 1 P2Maq | 3 P2Maq |
| 1 P3Maq | 3 P3Maq |
| 1 P4Maq | 3 P4Maq |
| 1 P22Maq | 2 P22Maq |
| 3 R1Mod | 5 R1Mod |
| 1 R4Mod | 2 R4Mod |

## 5 CONCLUSION

In this work was presented a hybrid decision support system, using the main properties of the techniques of Simulation and CPNs, with an Expert System for aid in its use. With the survey of the necessities and diagnosis, the construction of a generic model of the manufacture plant was possible, leading to a higher reliability and quality in the decisions to be taken.

Table 4: Scene 2

| PUS (Model and Matrix) | |
|---|---|
| Amount Production | 71 |
| PUS/Day | 2,42 |
| WIP | 97 |
| Busiest Resources | P1Mod, P2Mod,P3Mod,R1Mod |
| Busiest Resources | R2Mod, R4Mod,P1Maq,P2Maq |
| Busiest Resources | P3Maq,P4Maq,P6Maq,P7Maq |
| Busiest Resources | P8Maq,P9Maq,P10Maq,P13Maq |
| In Operation | 57,90% |
| Blocked | 28,24% |
| Wait for Resources | 13,85% |

The used techniques were adequate and had corresponded to the objectives established. The Simulation was efficient to improve the performance of the considered system. The CPNs has been adequate for structural analysis of the model and, in the tests presented, shown the structural validity of the scenes.

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