

## COMBINED USE OF MODELING TECHNIQUES FOR THE DEVELOPMENT OF THE CONCEPTUAL MODEL IN SIMULATION PROJECTS

José Arnaldo Barra Montevechi  
Rafael Florêncio da Silva Costa

Instituto de Engenharia de Produção e Gestão  
Universidade Federal de Itajubá  
Avenida BPS, 1303 – Caixa Postal: 50  
Itajubá, MG, 37500-903, BRAZIL

Fábio Ferreira Marins

Campus Universitário – Bairro Trindade  
Universidade Federal de Santa Catarina  
Florianópolis, SC, 88040-970, BRAZIL

Fabiano Leal  
Alexandre Ferreira de Pinho  
Fernando Augusto Silva Marins

Universidade Estadual Paulista  
Av. Dr. Ariberto Pereira da Cunha, 333  
Guaratiguetá, SP, 12.516-410, BRAZIL

José Tadeu de Jesus

PadTec  
Rodovia Campinas - Mogi Mirim (SP 340) – km: 118  
Campinas, SP, 3086-902, BRAZIL

### ABSTRACT

The objective of this paper is to utilize the SIPOC, flowchart and IDEF0 modeling techniques combined to elaborate the conceptual model of a simulation project. It is intended to identify the contribution of these techniques in the elaboration of the computational model. To illustrate such application, a practical case of a high-end technology enterprise is presented. The paper concludes that the proposed approach eases the elaboration of the computational model.

### 1 INTRODUCTION

In agreement with Brooks and Robinson (2001), conceptual model is “an independent software description of the model that is to be constructed”.

According to Law and Kelton (2000), conceptual model corresponds to one phase of the discrete events simulation methodology. Chwif and Medina (2006) affirm that the step of creation of the conceptual model is the most important aspect in a simulation study, although many books and analysts skip this step. For Wang and Brooks (2007), of all tasks involved in a modeling project, conceptual modeling is probably the one that has received the least attention and consequently is the least well understood. The verification, validation and output analysis phases have a strong element of mathematics, statistics or logic. However, the nature of conceptual modeling is quite different, so much that it is often described as being an art rather than a science.

According to Wang and Brooks (2007) the most used conceptual modeling technique is the flowchart (63%), mainly justified by its simplicity. Among the eight most common, techniques with less rigorous modeling rules are found, such as component list, text description, visual display and list of assumptions and simplifications. In this list of the eight most used modeling techniques, two have more rigorous rules: activity cycle diagram (ACD) and unified modeling language (UML).

Works such as Hernandez-Matias et al. (2008) point out the increasing utilization of the IDEF0 technique in analysis in manufacturing processes. Besides these authors, a large number of researchers have shown that IDEF approach methods can be used in simulation support. Jeong (2000) has used both IDEF0 and IDEF3 in the development of a simulation targeting the optimization of a scheduling system. On the other hand, Perera and Liyanage (2000) used both IDEF0 and IDEF1X to assist the collecting of input data for the simulation of manufacturing processes. Other researchers, such as van Rensburg and Zwemstra (1995), Al-Ahmari and Ridgway (1999), have shown the utilization of IDEF0, IDEFX1 and IDEF3 to assist the simulation of manufacturing processes.

In this paper, the Supplier, Input, Process, Output, Customer (SIPOC), flowchart and Integration Definition for Function Modeling (IDEF0) techniques will be conjointly used and applied in a practical case. The objective of this conjoint utilization is to apply each one of these techniques in the elaboration of the conceptual model and identify the contribution of these techniques in the elaboration

tion of the computation model, by using the Process Simulator®.

## 2 CONCEPTUAL MODELING

For Balci (2003), the conceptual model can be utilized as a control tool of the modeling and simulation process's requirements in order to evaluate simulation concepts, effectiveness and errors, as a basis for the modeling and simulation project, besides assisting in the computational model's verification and validation process.

Some authors present a step sequence for simulation, contradicting a false idea that simulation consists of the computational programming of a model. Figure 1 presents a proposal from Chwif and Medina (2006).

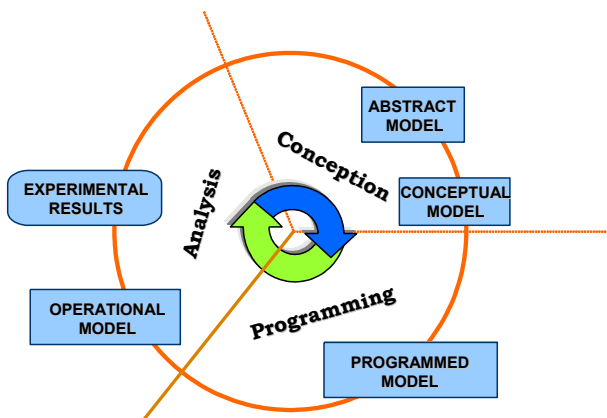


Figure 1: Step sequence for the simulation project  
Source: Adapted from Chwif e Medina (2006)

It becomes clear in the diagram proposed by Chwif and Medina (2006) a first modeling to be carried out already in the conceptual phase. To the modeling the name conceptual model is given. In the conception phase, the model in the analyst's mind (abstract model) must be represented in accordance with a simulation model representation technique, in order to turn it into a conceptual model, so that other people can understand it.

Authors like Perera and Liyanage (2000) affirm that the use of modeling techniques already in the conception phase increases the simulation models' quality and decreases the required time for the construction of these computational models. This is the main reason for many researchers to focus their works in obtaining a connection between modeling tools and simulation processes.

According to Chung (2004), it is important to the modeler to familiarize with the system to be modeled. In the majority of the cases the modeler does not have a knowledge of the system, when compared to the knowledge of the manager, process's specialists and labor.

It is usual among simulation practitioners a certain confusion regarding the concepts of conceptual and computational model. In his work, Sargent (2007) seeks to explain

the difference between conceptual and computational model. According to this author, a conceptual model is the mathematical, logical or verbal representation of a problem, whereas computational model is the conceptual model implemented in a computer. The conceptual model is developed through the analysis and modeling phases, and the computational model is developed through computational programming and an implementation phase.

Some researches have been presented with the objective of improving the conceptual modeling of simulation projects. Montevechi et al. (2007) used the process map during the phase of defining the system to be simulated. On the other hand, Leal et al. (2007) proposes the conceptual modeling highlighting the advantages of using IDEF0. The importance of the conceptual model is also pointed out in the work of Zhou, Zhang e Chen (2006). In this work, the authors propose that automation can assist in the improvement of the utilization of conceptual models in simulation. It is understood by automation the use of software that assist the development of the conceptual model, such as Microsoft Visio® and SmartDraw®.

## 3 CONCEPTUAL MODEL VALIDATION

Sargent (1992) points out the preoccupation regarding the validation since the conceptual modeling phase. According to the author, there are two kinds of conceptual model assumptions: structural assumptions (regarding the real world system's operation) and data assumptions. The first kind can be validated through observations of the real world system and discussions with the personnel specialized in the system. The author highlights that no one knows everything about the system. Hence, many people must be consulted in order to validate the conceptual model assumptions.

The literature presents some techniques for validation of the conceptual model, such as:

- Model duplication (Chwif and Medina 2006): efficient practice, but expensive, because it supposes the existence of two independent team developing models of the same system. This way, if both teams (operating independently) develop similar models, this would be a good model's validity indicator;
- Comparison with previous models (Chwif and Medina 2006): development of a model from another previously validated one;
- Face-to-face validation (Chwif and Medina 2006; Kleijnen 1995; Sargent 1992): discussion with specialists with the objective of reaching with these specialists the assurance to use the model (applied in both conceptual and operational models).

In the conceptual model, the validation follows a more subjective path, through the perception of the specialists and modelers. Chwif and Medina (2006) point out the verification and validation processes, clearly separating the conceptual and computational models, as shown in Figure 1. Now, in the case of the computational model, the validation receives the name of operational, using statistical data in order to compare results from the simulation with the ones from the real world.

An important issue during the conceptual modeling phase is the selection of the modeling technique, as it will be seen next.

#### 4 PROCESS CONCEPTUAL MODELING TECHNIQUES

For Hernandez-Matias et al. (2008), there is not a conceptual modeling method that can alone completely model a complex manufacturing process. As a result of the limitations of these techniques, different integrated modeling methods have been developed. During the 1990's, the work done by Kettinger, Teng and Guha (1997) listed more than 100 different conceptual modeling techniques, many times called process mapping.

Aguilar-Savén (2004) confirms that the selection process for the right process modeling technique is becoming more and more complex, not only due to the large number of available approaches, but also due to the lack of a guide that explains and describes the concepts involved in the many modeling techniques and tools.

In this work three conceptual modeling techniques were utilized: SIPOC, flowchart and IDEF0. These will be explained as follows.

##### 4.1 SIPOC

The tool name prompts the team to consider the Suppliers (the 'S' in SIPOC) of your process, the Inputs (the 'I') to the process, the Process (the 'P') your team is improving, the Outputs (the 'O') of the process, and the Customers (the 'C') that receive the process outputs.

A SIPOC diagram is a high-level picture of the process used as a tool by a team to identify all relevant elements of a process improvement project before work begins. It helps define a complex project that may not be well scoped.

##### 4.2 Flowchart

In a definition presented by Aguilar-Savén (2004), a flowchart can be defined as a formalized graphical representation of a programmed logical sequence, work, manufacturing process, or general structure. According to the author, there is not a specified date of its origin. The easiness of its use is one the main advantages.

Corrêa and Corrêa (2006) affirm that the flowchart is one of the most important process analysis tools. It is used as a visual representation of the production flow. It is also useful to have an idea of the entire process, the job of every part in the whole, of potential problems and improvement and simplification opportunities.

A flowchart outlines the information, people, equipment or material flows through the many process parts. Flowcharts are drawn with boxes containing a brief process description and lines and arrows showing the sequence of activities. The rectangle is the usual choice for a flowchart box, but different geometric shapes can differentiate kinds of activities. Moreover, colors and shadows can be utilized to draw attention to different kinds of activities, such as the most important ones in the process. While many representations are accepted, there must be a standardization of the used system, so that the flowchart can be easily understood.

A flowchart can be created for different levels within the organization. For instance, in the strategic level, they could show the core processes and their interactions. In this case, the flowchart would not have many details; however, they would provide an overview of the process. This identification of the process's core is often useful for future analysis.

Aguilar-Savén (2004) presents in her work a comparison of modeling techniques. According to the author, the flowchart presents the communication ability as strong point for the user, while for the modeler the strong points are the technique's flexibility and its simplicity. On the other hand, the technique's weak point for the user is the fact that it can assume a great extension in representing processes. The main weak point for the modeler is the fact that there are many different notations associated to this technique. This excess of notations is also discussed by Rosemann (2006), when affirming that flowcharts of all sizes and shapes have been popularized within the organizations.

##### 4.3 IDEF0

According to Aguilar-Savén (2004), the IDEF family is used according to different applications. The most important versions are the IDEF0, IDEF1, IDEF1X, IDEF2, IDEF3, IDEF4 and IDEF5. However, for business process modeling the most useful versions are the IDEF0 and IDEF3. More details on the application of the IDEF can be found on the website maintained by Knowledge Based Systems, Inc. ([www.idef.com](http://www.idef.com)).

The IDEF0 has graphic and text combined elements that are presented in an organized and systematic way, in order to obtain an understanding of the system, analysis support, construction of the logic for potential changes, requirements specification and visualization of the integration among the activities. An IDEF0 model is composed by

an hierarchical series of diagrams that gradually exhibits levels of details in the description of functions and their interfaces with the system's context.

The IDEF0 works with the following elements that relate with the functions:

- Inputs: represented by arrows; they are data or objects that are transformed by the function into outputs. The input arrows are linked by the left side, entering the function box;
- Outputs: represented by arrows; they are data or objects produced by the function. The output arrows are linked by the right side, coming out of the function box;
- Mechanisms: represented by arrows; they are the means through which the function is executed. The arrows representing mechanisms are linked by the bottom part with the function box;
- Control: represented by arrows; required conditions to produce the right output. Data or modeled objects as controls can be transformed by the function creating outputs. The control arrows are linked to the function box by the top part.

Hernandez-Matias et al. (2008) confirms that the method's flexibility resides in the capability of allowing an analysis of complex systems, where there is the need to study multiple levels in detail. Analyzing the different IDEF approaches, it is concluded that, according to the authors, the IDEF0 is the most widely version utilized in analysis of manufacturing processes.

## 5 APPLICATION

Padtec S/A is Brazilian company of high-end technology focused on the fabrication and development of equipments for optical communications. Due to this business branch own nature, some characteristics stand out, such as: the multifunctionality of the employees, the absence of standard methods to activities execution (being the employee responsible for choosing the method of executing the activity) and the dependence on the employee's manual and mental skills for assembling and configuring the product. This way, the company's manufacturing area is composed of six production cells, being each cell responsible for as-

sembling a group of equipments. The modeling was developed in the transponder assembly cell, once it represents 40% of the company's revenues.

Figure 2 demonstrates the research's main idea, being the real system represented by three modeling techniques. The computational model will be generated through the flowchart's structure, the information generated by the SIPOC and IDEF0, the simulation software's programming logic and quantitative data acquired in the real system.

It is important to highlight that there are three conceptual models from a single real system. The reason of that is to obtain information related to each modeling technique used. This information will help to get a faster and precise programmed model.

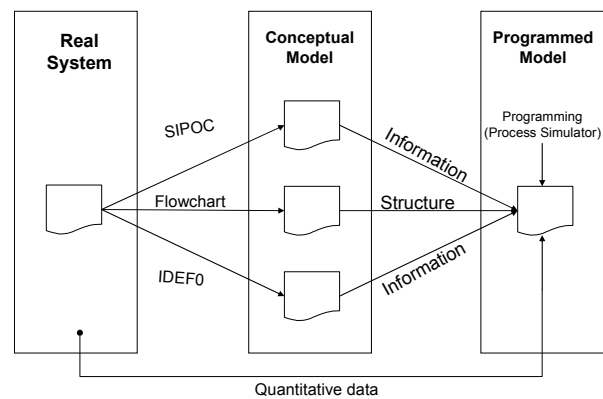


Figure 2: Proposed approach

A SIPOC diagram for the transponder cell was initially built, as shown in Figure 3. With this diagram it is possible to obtain a macro view of process inside the cell and the existing relations with other cells or departments. It is a vision of how the cell relates inside the factory. This diagram, in this initial moment, can generate important information for the modeler, such as identify which will be the inputs and outputs of the computational model. The box that represents the process that occurs inside the cell (assemble transponder) will be expanded in the following step, in order to identify which activities form the process and also verify the sequence of these activities.

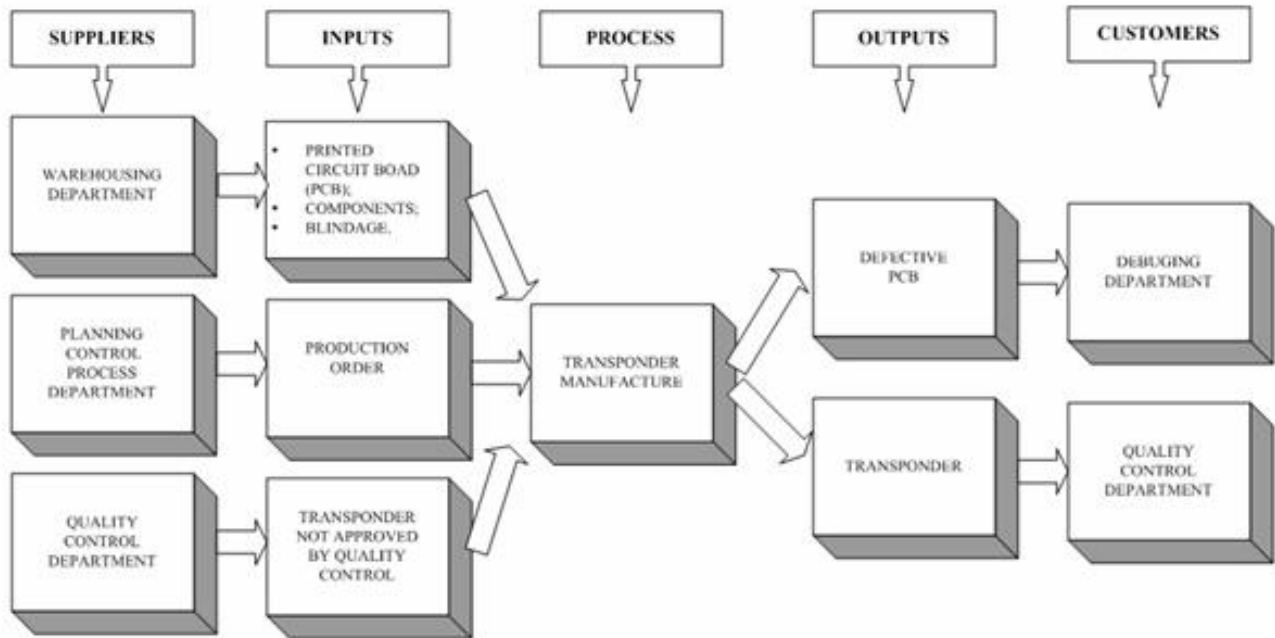


Figure 3: SIPOC diagram of the transponder cell

Although the employee is able to choose the method to execute the activity, the sequence of activities to manufacture the same product does not change. This way, a flowchart was built in order to identify the activities that consti-

tute the transponder's manufacturing process and also to represent the sequence of these activities, according to Figure 4.

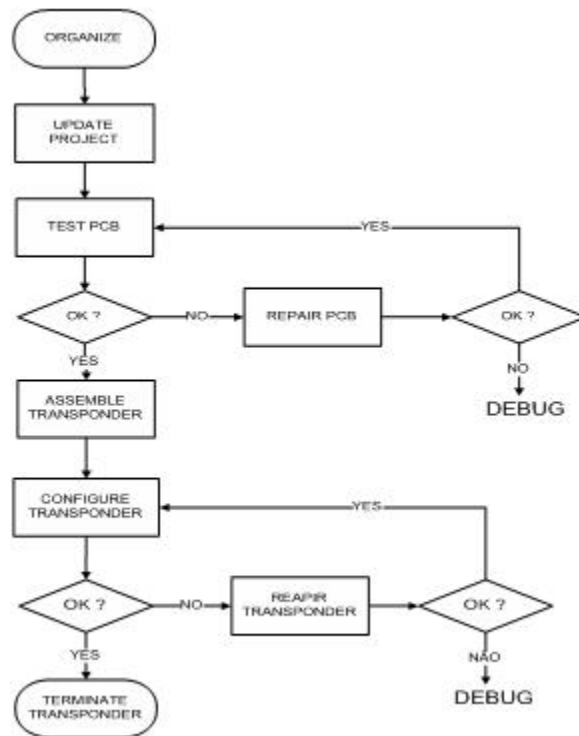


Figure 4: Flowchart of the transponder cell

Once the sequence of the activities is defined through a flowchart, the next step is the gathering of information on these activities, such as: inputs, outputs, controls and re-

sources. This information can be obtained through a IDEF0 diagram, showed in Figure 5.

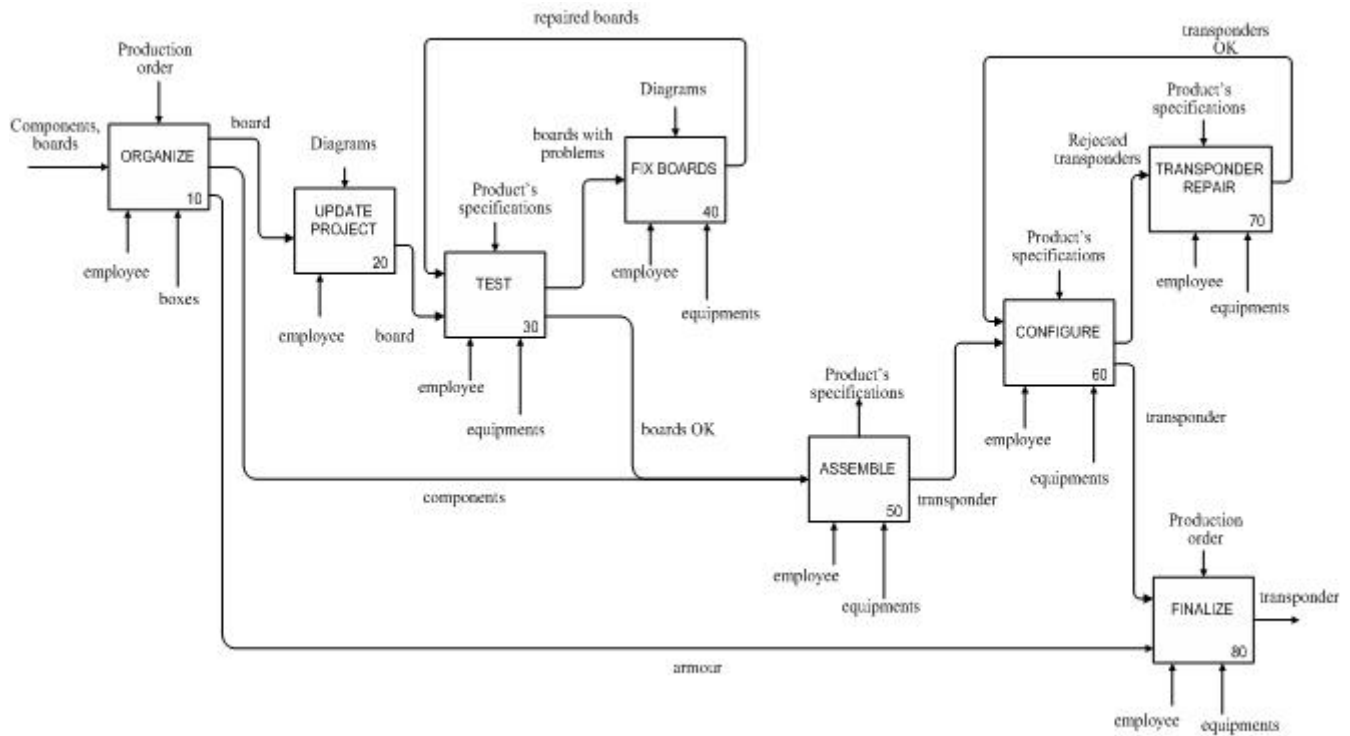


Figure 5: IDEF0 Diagram of the transponder cell

After the conceptual modeling, based on these three techniques, SIPOC, flowchart and IDEF0 (built on Microsoft Visio®), the following step is the creation of the computational model. In this moment, it is pointed out how practical this sequence of conceptual model is, once the built flowchart will be upgraded with simulation properties through the Process Simulator®, which executes the simulation from the flowchart built. Figure 6 shows the screen of the construction of the simulation's properties on Microsoft Visio®, where it is possible to input the time spent by the activity through a distribution of probabilities and se-

lect which employee or equipment will be utilized in this activity. It is also possible to built programming logics, not to mention other resources of the software.

Figure 7 shows the execution screen of the flowchart's simulation, being possible to analyze its dynamic behavior, to compare scenarios e and to obtain variables of interest.

It is highlighted the easiness of utilizing software that provides the execution of simulation of pre-built flowcharts.

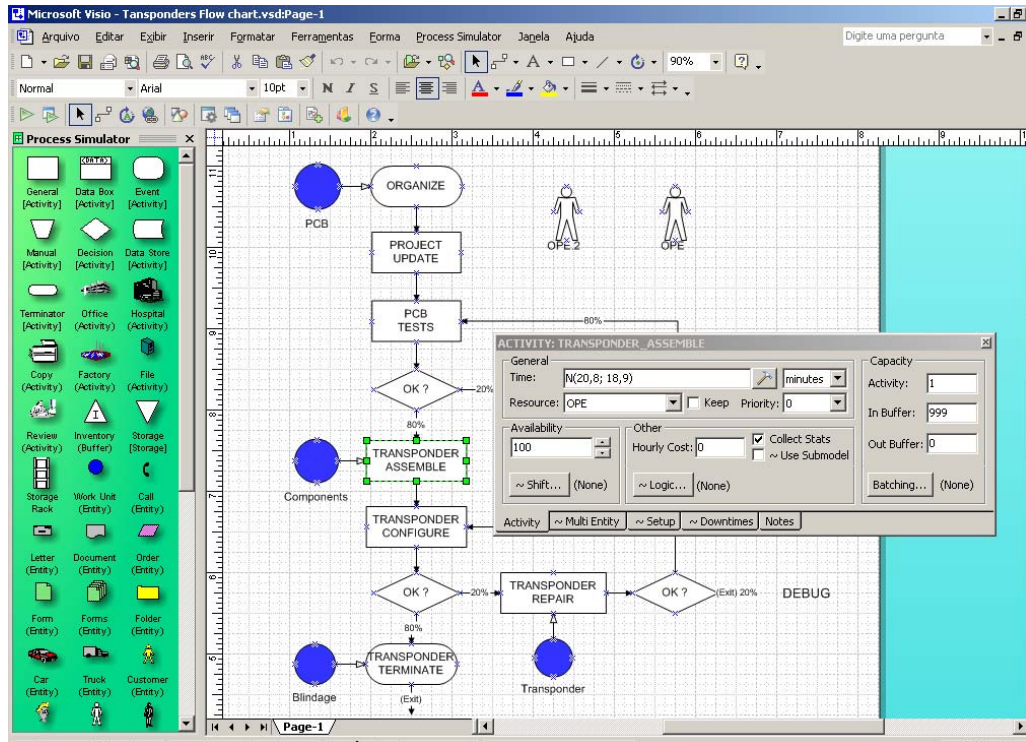


Figure 6: Microsoft Visio® screen for the simulation properties

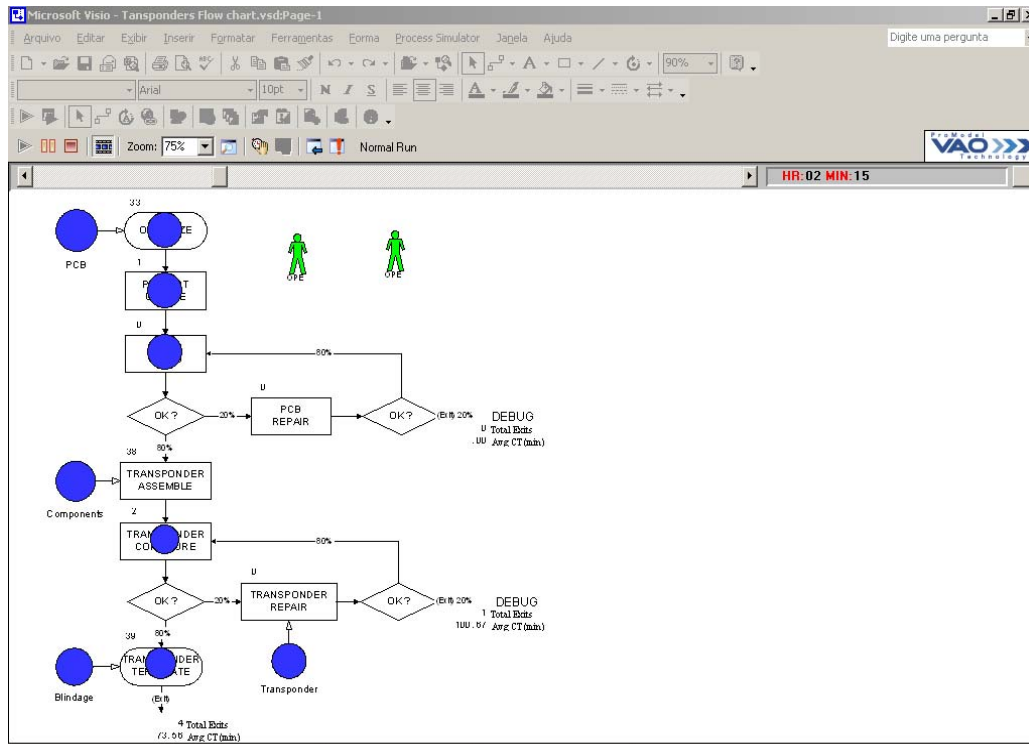


Figure 7: Process Simulator® screen executing the simulation of the built flowchart

The construction through those techniques of a conceptual model in a sequence of detail levels enabled the quick and efficient elaboration of a computational model.

Table 1 summarizes the contribution of each process mapping technique to the construction of a computational model for discrete event simulation.

Table 1: Contributions of the modeling techniques to the computational model

Technique	Contribution to the Computational model	Application
SIPOC	Identifies the possible entities that should be input in the computational model;	Boards, components, armour, and rejected transponders by quality control;
	Identifies the computational model possible outputs;	Boards with serious problems and manufactured transponders;
Flowchart	Identifies the activities that constitute the process;	Organize, update project, do tests, fix boards, assemble, configure, fix e finalize;
	Identifies the flows that an entity can follow inside the cell;	A board may not pass the tests and be sent to debugging or pass the tests and carry on to be assembled;
IDEF0	Identifies the rules that will be built in the logic of the computational model's simulator;	In the activity assemble, the rule is to combine the components according to the product's specifications;
	Identifies the demand of each activity for resources such as equipment and operators;	The activity fix requires one employee and one metal welding;

## 6 CONCLUSIONS

The main contribution of this paper is the conjoint use of three process modeling techniques. As observed, each one of the modeling techniques (SIPOC, flowchart and IDEF0) individually has a particular approach. However, the conjoint use of these techniques provides a better comprehension of the model to be simulated, as shown in Table 1.

Another advantage of the conjoint use of these three techniques was providing a greater agility in the elaboration of the computational model. This agility derives above all from the fact that the computational model was built by utilizing the conceptual model's structure, once this structure has the flowchart as basis.

More the complexity of the real system analyzed more the information needs to have a valid programmed model.

So that, the procedures suggested in this research will make easier the real system modeling. As a consequence the conceptual models will become richer in information

Moreover, the elaboration of three conceptual modelings allowed the company to utilize this information in improvement projects, such as rationalization, a cost management system, training of new employees, among others.

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#### AUTHOR BIOGRAPHIES

**JOSÉ ARNALDO BARRA MONTEVECHI** is a Titular Professor of Instituto de Engenharia de Produção e Gestão at Federal University of Itajubá, in Brazil. He holds the degrees of Mechanical Engineer from Federal University of

Itajubá and M.Sc. in Mechanical Engineer from Federal University of Santa Catarina, and Doctorate of Engineering from Polytechnic School of University of São Paulo. His research interest includes Operational Research, Simulation and Economic Engineering. His e-mail address is <[montevecchi@unifei.edu.br](mailto:montevecchi@unifei.edu.br)>.

**RAFAEL FLORENCIO DA SILVA COSTA** is a Production Engineering undergraduate student at Federal University of Itajubá. His research interest includes Operations Research and Simulation. His e-mail address is <[Rafael.florencio@yahoo.com.br](mailto:Rafael.florencio@yahoo.com.br)>.

**FABIANO LEAL** is a Professor of Instituto de Engenharia de Produção e Gestão at Federal University of Itajubá, in Brazil. He holds the degrees of Mechanical Engineer from Federal University of Itajubá and M.Sc. in the same university. His research interest includes Simulation, Operations Management and Work Study. His e-mail address is <[fleal@unifei.edu.br](mailto:fleal@unifei.edu.br)>.

**ALEXANDRE FERREIRA DE PINHO** is a Professor of Instituto de Engenharia de Produção e Gestão at Federal University of Itajubá, in Brazil. He holds the degrees of Mechanical Engineer from Federal University of Itajubá and M.Sc. in the same university. His research interest includes Operational Research, Simulation and Operations Management. His e-mail address is <[pinho@unifei.edu.br](mailto:pinho@unifei.edu.br)>.

**FERNANDO AUGUSTO SILVA MARINS** is a Professor of Engineering College – Campus of Guaratinguetá – São Paulo State University, in Brazil. He holds the degree of Mechanical Engineer from São Paulo State University, the M.Sc. in Operations Research from Instituto Tecnológico de Aeronáutica, and PhD in Operations Research from State University of Campinas. His research interest includes Operational Research, Simulation and Logistics. His e-mail address is <[fmarins@feg.unesp.br](mailto:fmarins@feg.unesp.br)>.

**FÁBIO FERREIRA MARINS** is a Production Engineering undergraduate student at Federal University of Santa Catarina. His research interest includes Logistics, Simulation and Lean Manufacturing. His e-mail address is <[ff.marins@uol.com.br](mailto:ff.marins@uol.com.br)>.

**JOSÉ TADEU DE JESUS** is a physician with postgraduate in Applied Physics by UNICAMP. He worked for 18 years in optical components and systems and now he is in charge as COO of Padtec. His e-mail address is <[tadeu@padtec.com.br](mailto:tadeu@padtec.com.br)>.