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SOFTWARE TOOLS FOR MODELLING AND SIMULATION OF MANUFACTURING PROCESSES

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***Abstract**: The increasing popularity of simulation has resulted in its widespread use for modelling and analysis of systems in various application areas such as manufacturing, modelling and analysing business processes. Modelling tools allow the process to be diagrammed. Process modelling is crucial because it depicts the business, the relationships, and the flow of information.*
Process analysis tools are used to enter, view, and track the process inputs. These tools, like modelling tools, must show different views of the results. Most process analysis tools are packaged with modelling tools. Process analysis tool selection considerations are basically the same as those of modelling tools.

Keywords: *CASE, modelling tool, simulation packages*

1. INTRODUCTION

Modelling tools allow the process to be diagrammed. Process modelling is crucial because it depicts the business, the relationships, and the flow of information. With this information, the impact or potential ripple effect of changes can be determined (Morris & Brandon, 1993).
In process modelling, activities and their connecting links are labelled and assigned to all necessary levels (Roberts 1994).
Modelling tool-selection issues are methodology, alternative views, from of input, simulation, and standardization. Process modelling may be done with flowcharts, tree diagrams, fishbone diagrams, hierarchy charts, computer-simulated models, and mathematical models. One of the most popular methods is flowcharting. Flowcharts graphically illustrate the steps of an activity. Descriptive symbols are used for each step and arrows indicate the flow. The flowcharting steps are Define steps and sequence (Yu & Wright, 1997).

1. Identify all relationships and decisions.
2. Draw straight-line representation of all work steps.

Simulation tools, while not specifically designed for process design and re-engineering (PDR), provide additional methods to analyse the dynamic nature process. "Fundamental to the re-engineering effort is the ability to simulate the changes that are being proposed" (Morris & Brandon 1993). Simulation is dynamic process modelling. Simulation allows the user to predict the behaviour of a system under certain circumstances without actually building the system. Simulation is just an approximation of the physical system, but it allows changes to be rapidly incorporated and tested under a variety of conditions. Through computer simulation, process functions, optimal settings, and the effect of various inputs may be determined. Basic simulation inputs are task time, resources, and demand, while the outputs are cost, throughput, cycle time, utilization, and bottlenecks (Petrozzo & Stepper , 1994).

2. BENEFITS OF ENTERPRISE MODELING

Modelling tools are computerized instruments used to support the application of modelling methods. Support in designing enterprise models through the use of computerized tools can play a crucial role in increasing the efficiency of the development process. The general benefits of computer support:

- All relevant information is entered in a structured, easy-to-analyse form, ensuring uniform, complete documentation. The incorporation of a user-friendly graphical interface offers a comfortable means of creating and modifying the necessary diagrams. Changes in one part of the documentation are automatically updated in other locations and thus need only be performed once.
- Referencing stored design to its creation date enables die different versions to be managed in a comfortable fashion. Versions are overwritten only if the user expressly wishes it; otherwise, each modification is maintained as an independent version.
- The use of a tool facilitates conformance to a fixed procedural model. Consistency checks ensure that modelling activities are not permitted until the preceding level has been completely processed.
- The graphical tool interface enables the information objects to be categorized in a meaningful, content-related manner. In particular, reclassifying basic information units such as attributes into information objects.

3. CHARACTERIZATION OF MODELLING TOOLS

We can distinguish different groups of tools for enterprise modelling (see *Figure 1).* In relation to the different tasks of enterprise modelling, each group shows its special support profile (Salvendy, 2001).

	Programming Environments	CASE Tool	Drawing Tool	ERP Software
Documentation of Process		•	●	●
Analysis of Process		•	●	•
Recruitments Definition		•	•	●
Design Specification	•	●		●
Implementation Description	●	●		●

Figure 1. Groups of tools for enterprise modelling

The first group can be seen as modelling tools in a broader sense are programming environments. Programming environments such as Borland JBuilder clearly emphasize the phase of implementation description. They describe a business process by the language of the software application that is used to support the process performance. In few cases, programming languages provide limited features for design specification.

CASE tools, on the other hand, support a specific design methodology by offering data models and function models (e.g., the entity relationship method (ERM) and structured analysis and design technique IDEF0).

In contrast, drawing tools and ABC (Activity Based Costing) Flow charter support the phases of documentation and, to a certain extent, analysis of business structures and processes. The emphasis is on the graphical representation of enterprises in order to better understand their structures and behaviour. Consequently, drawing tools cannot provide database features such as animating and simulating process models, analysing process times, and calculating process costs.
The last group encompasses standard software systems, such as Enterprise Resource Planning (ERP) systems like those from SAP, Baan, or Oracle. ERP systems, offer greater flexibility with respect to customisation, provide support for data management. The main weakness is in active analysis of business structures—that is, ERP tools typically do not offer tools for simulation process alternatives.
Because all the modelling tools presented focus on different aspects, none of the systems is suitable for handling the entire systems development process. However, ERP systems are opening up more and more to the modelling and analysis level, endeavouring to support the whole system life cycle.

4. ERP and the SME

Generally, all manufacturing SMEs (and particularly enterprises working in the mechanical sector) need to frequently innovate their products, both to create new products and to enhance the quality of the existing ones; this policy cannot be practically applied because of the long time and the high costs required for new products design.
Enterprises need the technique and software can help a manufacturer or other business manage the important parts of its business, including planning products, purchasing parts, maintaining inventories, interacting with suppliers, providing customer service and tracking orders. Typically, an ERP system uses, or is integrated with, a relational database system. The deployment of an ERP system can involve considerable business process analysis, employee retraining and new work procedures.
May be considered the following category of enterprises: small, middle and large (see Figure 2). It is necessary to understand, that using these methods is effective not for all enterprises. For SME Middle Integrated systems are obviously more suitable.

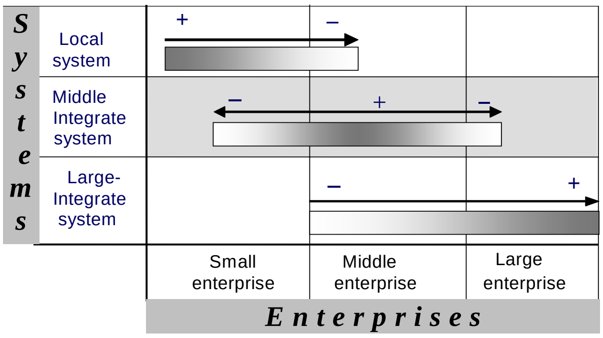

Figure 2. Modelling system classification

ERP systems often wreak havoc in companies. Statistics show one in four companies admit suffering a drop in performance. The most common reason for the performance problems is that everything looks and works differently from the way it did before. When people can't do their jobs in the familiar way, and haven't yet mastered the new way, they panic, and the business goes into spasms. Process modelling technique that needs to be used throughout an SME needs to be readily accessible with the minimum of training and support.
The main reason of seldom using ERP systems in SME is its high cost.
Enterprise engineering takes a systems approach to designing an enterprise. The entire enterprise not simply isolated processes, are designed in relation to a vision and set of enterprise strategies. This implies the need for a top down approach, which considers all aspects of the enterprise, including its processes, resources, organizations (functions) and control structure. The modelling method defined in this research must take into account the top-down nature of the problem and the need to integrate the various aspects of the enterprise. Most modelling methods currently available focus on one or a few aspects at a time. Even in a suite of methods such as the IDEF methods, integration across methods is ad hoc (Mayer, 1992).

5. MODELLING SOFTWARE TOOLS

CASE (Computer Aided Software Engineering) – a technique for using computers to help with one or more phases of the software life-cycle including the systematic analysis, design, implementation and maintenance of software. Adopting the CASE approach to building and maintaining systems involves software tools and training for the developers who will use them.

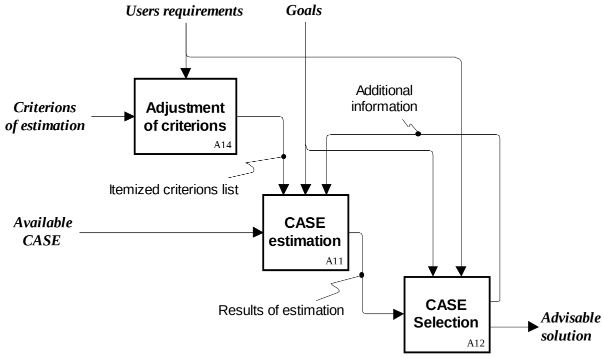

Figure3. The CASE system selection

A variety of tools are used for process modelling within business process reengineering. Among these, the data and functional modelling tools were most widely used. Thus, the choice of a process analysis tool depends on the characteristics of the process investigated. Order of CASE tool selection is introduced in Figure 3.

6. REQUIREMENTS OF MODELS

Models are based on certain assumptions about the system and its components and how the system is going to be operated. Then there are the assumptions about the nature of the disturbances that will impact the system and the range of responses to these disturbances. The hierarchy of control and the flow of information also have to be represented in the model (Applegate, 1986).

- *Complexity vs. simplicity:* Modelling involves compromises in deciding how much detail to represent. A large amount of detail means that the model should be a more precise representation of reality, but the disadvantages are that the model will be more difficult to verify and validate, be harder for users to understand, and take longer to develop. A simple model may not represent the system adequately and thus may give inaccurate predictions and omit key decisions or useful.
- *Flexibility:* A model may be used to support decision-making as the system evolves over time. That is, from initial concept through planning, detailed design, installation, and operation, there is a need for models to support decisions. While no one single model will support all decisions, it is desirable for model to be useful at a number of different stages in system evolution. This means that the model should permit changes in the system modelled. Some of these changes may relate to the

structure of the system, such as the number of machines or service representatives, the way in which jobs or customers move through the system, or the way in which the control hierarchy is set up. Other changes may relate to the values of parameters such as the frequency of machine failures or the demand rate. A model or a modelling approach has to be evaluated with respect to the ease of making both these sorts of changes.

• *Data requirements:* While there is often a great deal of data available in manufacturing or service, it is rare that the data are in the form required by the model. At the planning stage, there is often doubt as to the applicability of data collected from different systems in different environments, while when the system is operational, the data may well only apply over a limited range of operating conditions. Thus, a model should use the least amount of data required in order to make adequate predictions, and an important component of the validation of a model is assessing the sensitivity of the model to errors in the data.

• *Transparency:* Since the model has to be accepted by its users, it is desirable that the assumptions and procedures used in the model be reasonably transparent to others beside the model developer. The developer should be able to convince the user that the model is a reasonably accurate representation of reality.

• *Efficiency:* Models can consume significant resources, both in their development and in their use. Modelling approaches differ in their requirements on the knowledge, skill, and elapsed time required for development. Since most models will be implemented on a computer, such issues as running time and storage requirements can also be important.

• *User interface:* If a model is going to be of real value, it should be usable by managers rather than only by the model developer. A user interface is essential in order to guide the user in the correct use of the model, ensuring that it is clear what data should be provided and avoiding any ambiguity in interpreting the results.

Applying special simulation programs can solve the management problems. The computer programs make easier the analyses and the optimisation of the system utilization during its work. The timetable of production, work pieces flow and tools flow should be adapted to the current situation in such a way that production plans should be realized on time with the lowest possible costs. The simulation programs with possibility of modelling of the whole system can both support the management staff in operation of the manufacturing system and in the training of the staff.

7. SIMULATION SOFTWARE

The most important feature for a simulation software product to have is *modelling flexibility* or, in other words, the ability to model a system whose operating procedures can have any amount of complexity. Note that no two systems are exactly alike. Thus, a simulation package that relies on *a fixed* number of modelling constructs with no capability to do some kind of programming in any manner is bound to be inadequate for certain systems encountered in practice. Ideally, it should be possible to model any system using only the constructs provided in the software - it should not be necessary to use routines written in a programming language. The following are some specific capabilities that make a simulation product flexible (Law, 2000):

- Ability to define and change attributes for entities and also global variables, and to use both in decision logic (e.g., if-then-else constructs)
- Ability to use mathematical expressions and mathematical functions (logarithms, exponentiation, etc.)
- Ability to create new modelling constructs and to modify existing ones, and to be able to use new or modified modelling constructs in current and future models.

The second most important feature for a simulation product is *ease of use* (and ease of learning), and many contemporary simulation packages have a graphical user interface to facilitate this. The software product should have modelling constructs that are neither too "primitive" nor too "macro".

Hierarchical modelling is useful in modelling complex systems. *Hierarchy* allows a user to combine several basic modelling constructs into a new higher-level construct.

The software should have good *debugging aids* such as an interactive debugger.

Fast model execution speed is important for certain applications such as large models and models in which a large number of entities must be processed.

A feature that is currently of considerable interest is the ability to *import data from* (and *export data to) other applications* (e.g., an Excel spreadsheet or a database).

It is desirable for a simulation software package to *automatically simulate different scenarios that iterate on some model parameter,* such as the number of machines in a workstation for a factory. It should then be possible to plot some performance measure (e.g., average time in system for the factory) as a function of the parameter being iterated.

Occasionally, one might have a complex set of logic written in a programming language that needs to be integrated into a simulation model. Thus, it is desirable for a simulation package to be able to invoke *external routines.*

Another useful feature is that *the state of a simulation can be saved at the end of a run* and used to restart easily the simulation at a later time.

7.1. Comparison Methodology

In figure 4 are introduced major components and functions, which are necessary take into account by the simulation packages selection.

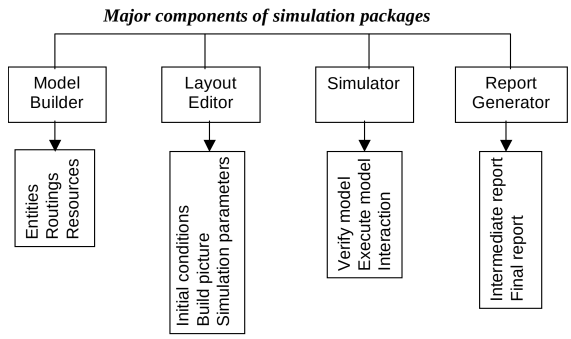

Figure 4. Major Components of Simulation Packages

Modelling capabilities

- *Goal Centred*, this means the process or reengineering goals are identified first and then the reengineering or improvement is carried out in agreement with the goals.
- *Roles*, it determines if the software tool can identify the different roles in the process. Roles can be the activities as performed by a person. Hence this is very useful in reengineering.
- *Data flow*, does the software use data flow diagrams, IDEF etc. to model the process.
- *Front end analysis*, can the tool check the model for syntax and logic. This way the model can be corrected before it is run.
- *Ease of modelling*, how easy is it to model the process, in terms of the graphical drawing and the data entry.
- *Level of detail*, how detailed can the model be drawn. This indicates the accuracy of the model.

Simulation capabilities

- *Time*, this feature identifies if the tool can track time. This is very useful in determining the duration of a ‘to-be’ operation from start to finish.
- *Cost*, can the tool track the cost changes as it is simulated.
- *Animation/ graphical capability*, a visual representation of a tool is very effective in analysis.
- *Discrete event modelling*, most activities do not occur in a fixed predictable period of time. Thus an effective tool should be able to vary the timing of events, tasks and processes to generate a realistic picture.

Analysis capability

- *Reasoning*, can the software reason with the information supplied and take decisions accordingly. The reasoning would be done through a knowledge shell or expert system stored in the tool.
- *Output analysis*, can the tool analyse the output for a process run. It refers to the ability of the tool to present the output in an understandable and effective format and drawing conclusions.
- *What-if analysis*, does the tool provide a means for simulating and considering the effect of different scenarios.
- *Top-down, bottom-up and outside-in analysis*, does the tool have the flexibility to map the process from bottom-up and top-down.

7.2. Features and Benefits of Selected System

For implementation of system analysis was used CASE (Computer-Aided Software Engineering) tool produced by *Meta Software*, which includes some parts. For models creation was used *WorkFlow Modeler* and for dynamical models *WorkFlow Simulator.* It is general-purpose simulation package. The *WorkFlow Modeler* a computer-based, graphical interactive modelling tool, which based on IDEF standard. The method used for describing the system and for analysing the existing system problems.

The *WorkFlow Simulator* permits the study of a proposed process redesign. Simulation takes the static model created in the *WorkFlow Modeler* and places it in a dynamic work environment.

WorkFlow Modeler is a mature, proven tool that has helped capture and represent the complexity of actual business processes at thousands of sites worldwide.

Easy to use – WorkFlow Modeler’s elegant simplicity and short learning curve have made it the tool of choice for process modelling. Because it automates much of the model drawing, you can focus on the model’s meaning and results, rather than its creation.

Features structured methodology/approach – WorkFlow Modeler utilizes IDEF (Integrated DEFinition Method), a popular, public domain notation in use for more than 25 years. IDEF captures the business system in a visually clear and accurate model.

Unlike simple flowcharting tools, *WorkFlow Modeler* supports IDEF0 for process modelling (IEEE Standard 1320.1 and FIPS Standard 183) and IDEF1X for data modelling (FIPS Standard 184). Data modelling gives ability to track entities (record types and their relationships), attributes (fields), and their data types.

Facilitates communication – Because of *WorkFlow Modeler’s* standard notation, everyone – management, business analysts can read and comprehend the models. It provides a common language for analysing and working together to improve specific business processes.

Flexible – The tool was designed with utmost flexibility in mind. It encourages compliance with standard IDEF notation by prompting you to add information required by the methodology, but it also gets you override these suggestions to allow for special cases or the use of variables.

Supports Activity-Based Costing – Activity-Based Costing lets you associate cost information with a model and add this cost information directly to the model. By linking these factors, is possible to perform financial analysis within the same framework as process analysis. For further analysis, the cost data can also be exported to a spreadsheet or to other financial analysis tools.

Compatible with other tools and environments – WorkFlow Modeler supports a variety of techniques for importing and exporting information. The Interface Definition Language (IDL) standard, widely used by government organizations and contractors, is used to share information between tools that support IDEF0. *WorkFlow Modeler* also supports the Activity Modelling Language (AML), and the Structured Modelling Language (SML) to import and export data and process models from application development tools.

8. CONCLUSION

Every process is unique in its characteristic because of the way in which the people, equipment, tools and practices interact to generate the end result. Thus, the choice of a process analysis tool depends on the characteristics of the process investigated.

Process analysis tools are used to enter, view, and track the process inputs. These tools, like modelling tools, must show different views of the results. Most process analysis tools are packaged with modelling tools. Process analysis tool selection considerations are basically the same as those of modelling tools. Typically, process modelling and analysis tools:

1. Provide system visualization through system diagrams.
2. Are PC based.
3. Are easy to learn to use and scalable.
4. Provide analysis and performance measures of static system.
5. Provide modelling of dynamic behaviours of system.

For analysis of manufacturing systems in our department was selected CASE tool produced by *Meta Software*. For models creation was used *WorkFlow Modeler* and for dynamical models *WorkFlow Simulator.*

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