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MODELING BUSINESS PROCESSES WITH SIMULATION TOOLS

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ABSTRACT

This tutorial provides an overview of business process modeling tools for re-engineering, demonstrates the suitability of simulation for BPR and highlights the modeling considerations. A simulation exercise is presented to illustrate how ServiceModel, a popular modeling tool, may be used to simulate the financial, human resource, and production elements of a business. The model is aimed at returning the simulated business to profitability by smoothing out the work backlog, maximizing resource utilization, and reducing expenses.

1 BUSINESS PROCESSES & RE-ENGINEERING

In the past 15 years, simulation efforts have focused on production processes. This has contributed to significant productivity and quality improvements in manufacturing processes. In the next five to ten years the real payoff for simulation will come from simulating business processes. The increasing competitive pressure to minimize the "time" it takes to service customers, increase profits, and develop new products promises a broad range of applications for simulation in Business Process Re-engineering.

Before delving right into simulation and the use of modeling tools , it is important to define what a business process is and summarize the principles of business process re-engineering. All service processes and processes that support production (e.g. order management, engineering changes, payroll, product design) can be considered business processes. A business process consists of a group of logically related tasks that use the resources of the organization to provide defined results in support of the organization's objectives (Harrington, 1991). Some typical examples of business processes are listed below:

- Product Development Processes - Product design, testing, configuration, and documentation processes.
- Order Management Processes - Purchasing, contracts, receiving, shipping, storage, materials management
- Financial Management Processes - Payroll, ledger control, taxes, accounts receivable, accounts payable
- Information Management Processes - Database management, networking, client-server applications
- Human Resource Processes - Hiring, placement, personnel services, training

Re-engineering begins with a basic assumption that the hierarchical, departmentalized structure of most businesses today is fundamentally flawed and doomed to fail. And, only through a radical reinvention of the value-added processes required to produce a product or service can a company hope to survive the intense competition of the future.

Re-engineering business processes involves people, processes and technology. Mark Youngblood, in his book "Eating the Chocolate Elephant", lists 32 ways to improve business processes. Most of these principles are fundamentals of Industrial Engineering which have been applied to production problems for decades. Nevertheless, it is worthwhile to mention some of them because they are the main reasons for why we want to simulate business processes.

- Eliminate duplicate activities
- Combine related activities
- Eliminate multiple reviews and approvals
- Eliminate inspections
- Simplify processes
- Reduce batch sizes
- Process in parallel
- Implement demand pull
- Outsource inefficient activities

- Eliminate movement of work
- Organize multi-functional teams
- Design cellular workplaces
- Centralize/Decentralize

Re-engineering gurus, Michael Hammer and James Champy, note in their book Reengineering the Corporation that only about 30 percent of the re-engineering projects they have seen were successful. Harold Cypress, in his February 1994 OR/MS Today article, defines the re-engineering that took place in the past 4-5 years as "first generation" re-engineering. He states that not much MS/OR thinking was used in first generation re-engineering and predicts that "second generation" re-engineering will support a greater solution space with a broader use of proven Operations Research tools and solutions. This leads to a discussion of modeling tools for business process re-engineering.

2 BUSINESS PROCESS MODELING TOOLS

When asked the question, "If you were to rebuild your business from ground zero, what would you do differently?", the answer can usually best be described with a model. Whether the answer takes the form of a narrative, a flow diagram, or a simulation model, one needs to define the processes which take inputs such as raw materials or potential customers and turn them into outputs such as products or services.

Over the past few years, several new software tools have been developed specifically for modeling business processes and workflows. Most of these tools define business processes using graphical symbols or objects, with individual process activities depicted as a series of boxes and arrows. Special characteristics of each process or activity may then be attached as attributes of the process. Many of these tools also allow for some type of analysis depending on the sophistication of the underlying methodology of the tool.

Analysis and modeling tools can be broken into three categories:

1) Flow Diagramming Tools: At the most basic level are flow diagramming and drawing tools that help define processes and work flows by linking text descriptions of processes to symbols. Typically, flowchart models provide little if any analysis capability. Examples of flow charting tools are ABC Flowcharter from Micrografx, EasyFlow from Haventree Software, and FlowCharting 3 from Patton & Patton.

2) CASE Tools: These tools provide a conceptual framework for modeling hierarchies and process definitions. They are typically built on relational databases and include functions that provide linear, static, and deterministic analysis capability. Examples of CASE tools include Meta Software's Design/IDEF and Workflow Analyzer, TI's Business Design Facility, and Action Technology's Action Workflow. Because of the effort and commitment required to fully understand the specific modeling methodology employed, CASE tools are sometimes referred to as "religious tools".

3) Simulation Modeling Tools: Simulation tools provide continuous or discrete-event, dynamic and stochastic analysis capability. Furthermore, simulation tools typically provide animation capabilities that allow the process designer to see how customers and/or work objects flow through the system. Examples of simulation modeling tools for business process modeling include ServiceModel from PROMODEL Corporation, SimProcess from CACI, and Extend+BPR from Imagine That.

2.1 Simulation -- The Ideal Tool for BPR

Based on our own customer surveys, we have discovered that the use of process modeling tools thus far has focused on modeling the current (or AS-IS) state of a business. Granted, understanding the current processes provides some value, but it also limits the imaginations of the re-engineering team when it comes to designing future processes. Furthermore, we have found that in over 80 percent of re-engineering projects, the modeling tools of choice have been flowcharting tools.

Although static modeling tools offer help in understanding the overall nature of an existing business process, they lack the ability to accurately predict the outcome of proposed changes to that process. In general, static modeling tools are deterministic and independent of process sequence. Furthermore, they lack the ability to model physical elements of a system such as the facility or office layout and movement of entities through the facility.

On the other hand, simulation tools provide ways to model entity flow (work flow or customers) including parallel flows, and the dynamic behavior of a business process. Realities such as randomness, uncertainty and interdependencies of resources can be accurately modeled using a simulation tool.

3 MODELING & ANALYSIS CONSIDERATIONS

Modeling business processes helps evaluate the quantitative business performance measures that are usually internal to a business. The types of questions answered by simulation can be categorized as either process design related or process management related. A list of typical questions follows.

Process Design Decisions

a) What is the total process cycle time?
b) What is the maximum throughput capability of the process?
c) What is the capacity of the service and waiting areas where the process is performed?
d) What are the equipment and technology requirements to meet the service demand?
e) How long do customers have to wait before getting serviced?
f) Where should the service and waiting areas be located?
g) How can workflow and customer flow be streamlined?

Process Management Decisions

a) What is the best way to schedule personnel?
b) What is the best way to schedule appointments for customers?
c) What is the best way to schedule carriers or vehicles?
d) How should the resources be assigned to tasks?
e) Which customers or tasks should be serviced first?
f) How should carriers or vehicles be scheduled?
g) How can we schedule maintenance for equipment and facilities?
h) What is the best way to deal with unexpected situations or emergencies?

3.1 Modeling Considerations

Since, by definition, business processes are service processes, we need to describe the unique characteristics of service systems and their implications in modeling. Service systems represent a class of processing systems where entities (customers, orders, work, etc.) are routed through a series of service stations and waiting areas. Although certain characteristics of service systems are similar to manufacturing systems, service systems have some very unique characteristics. Following are several special characteristics of service systems and their modeling considerations.

3.1.1 Entities are Often People

Queuing factors can cause people to change their minds, resulting in changes to the states of entities, or changes to their routing. Examples of such situations are balking, jockeying, and reneging. Balking is where a customer attempts to enter a queue, sees that it is full, and leaves. Jockeying is where a customer moves to another queue that is shorter in hopes of being served sooner. Reneging is where a customer enters a waiting line or area, gets tired of waiting, and leaves. Modeling these types of situations is complex and usually involves programming logic to properly describe the system behavior.

3.1.2 Arrivals are Usually Random and Cyclic

Interarrival times can best be represented by an exponential distribution. Arrivals may contain single or multiple entities at a time. Furthermore, arrival patterns are somewhat predictable based on time of day, day of week, etc. Accurate representation of arrival distributions and cycles is essential to building valid models of service systems.

3.1.3 Resources are Often People

Typically, resource allocation and task selection decisions are made on the spot by the resources in the system. A change in the state of an entity (a customer whose order is lost) may preempt a resource (a supervisor) from an existing task. Or, a change in the state of queue (a jump in the number of customers waiting in line) may require allocation of new resources (additional servers). Modeling this complex behavior of human resources may require programming logic in order to accurately represent the situation in a model.

3.1.4 Processing Times and Requirements are Highly Variable

Entity processing tends to be highly variable and dependent on the individual entity or the resource providing the service. A change in the state of a queue (number of customers in line) may cause a resource (cashier) to work faster, thereby reducing processing time. A change in the state of an entity (e.g. an angry client) may cause a resource to work faster to complete the service. Or, a change in the state of the resource (e.g fatigue) may change the service time. Modeling implications include the use of user-defined (empirical) distributions or programming logic to represent the variability resulting from changes in state.

3.1.5 Lack of Steady-State Behavior

Because arrivals are cyclical and random, service systems rarely reach steady state. Therefore, it is appropriate to view the operations of a service system in terms of time windows (periods) and define the model elements accordingly. For example, it is most appropriate to define a 24 hour day in terms of three periods (morning, afternoon, and evening) for an around-the-clock service system, and define the arrivals of customers and shifts for resources in terms of those windows.

3.2 Simulation Procedure Considerations

Simulation models can provide the most accurate and insightful means to analyze and predict the performance measures of a service system. However, when simulating and analyzing service systems, one must be aware of the dangers of using incorrect procedures which can result in erroneous results.

Because service systems rarely reach steady state, questions such as "How long to run a model?" or "How many replications to run?" become very important factors in making decisions from the analysis of model results. Since most design and management decisions in service systems involve answers to questions about transient conditions, it is most appropriate to study the performance measures in transient behavior. If the system performance under normal conditions need to be studied, the values of performance measures must be evaluated for each time window (or period) and not for the entire simulation run.

Most service systems are usually designed or managed with spreadsheet analysis using average system performance measures. Frequently, they fail to meet expectations. The reason for this is the fact that static and linear calculations ignore the affects of variability and queuing on system performance measures. For example, making a decision about the size of a waiting area based on the average number of customers in queue is not appropriate because the situation in which many customers arrive at the same time results in the maximum value of the number of customers waiting. Thus, the maximum value of this statistic is one of the most useful performance measures in designing a service facility.

Another procedural consideration worth mentioning is the analysis of resource utilization. In systems where arrival patterns and staff schedules are different over the course of a day (three periods), analyzing the utilization of resources over the entire simulation run is meaningless. It is most appropriate to analyze the resource utilization over each period in which the same arrival patterns and shift assignments are present.

4 MODELING BUSINESS PROCESSES

One of the major obstacles that has prevented simulation from becoming a mainstream business process modeling tool is that there are few connection or interface capabilities between simulation software and other process modeling tools such as flowcharting and CASE tools. Another obstacle has been the expertise required to build models with most simulation languages. ServiceModel, a breakthrough tool in modeling, eliminates these obstacles by providing a simple, yet powerful, import facility to utilize flowcharting models or models designed by CASE tools. Models that used to take weeks or months to build can now be built in hours or days with ServiceModel.

Assume that you have created a model of a business processes using a flowcharting tool. First, you cut and paste the processes that you wish to simulate from the flowcharting tool into ServiceModel. Then, you place the physical ServiceModel elements such as resources, entities, and queues over the top of that flow diagram. Finally, you define the details about the model elements. When you run the simulation, you have in essence put your process map in motion.

Assume another situation where you have created a model of a business processes using a CASE tool. Not only can you use the graphical depiction of your business process model, but you can also use the model data such as process lists, processing times, resources, etc. With a seamless link between the CASE tool and ServiceModel, the transition from the hierarchical model to simulation is even smoother. One such interface exists between ServiceModel and Meta Software's Design/IDEF tool. Because Meta's IDEF tool provides the capability to flatten the model hierarchy and also captures entity, resource, location, and processing information, ServiceModel can automatically simulate the business process.

The ServiceModel approach to modeling business processes offers a phased approach that can utilize the benefits of flowcharting models and CASE tool based models. This approach combines the quick and easy depiction of process maps and the hierarchical definition of business processes with the power of discrete-event simulation.

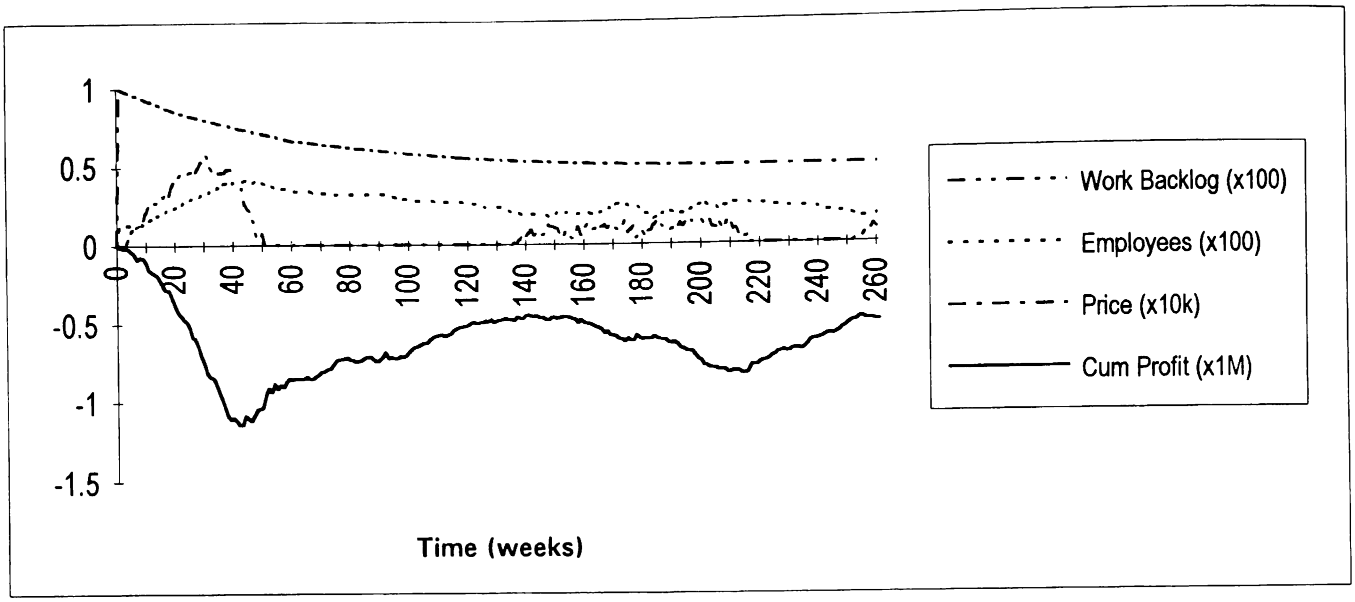

Figure 1: Output Graph from the Business Simulation Exercise

5 BUSINESS SIMULATION EXERCISE

Recently, through innovative software games like SimCity and SimEarth, the benefits of simulation have received widespread exposure. Furthermore, many top business schools are now including case studies involving simulation of business processes in MBA programs. Simulation models allow business students to practice solving business problems the same way air lines use flight simulators to train pilots.

The objective of this exercise is to solve a simulated business problem involving production, resource and financial management issues. Solving the problem means returning the business to profitability by smoothing out the work backlog, maximizing human resource utilization and reducing expenses. An operational graph of the simulated process is shown in Figure 1. This graph shows the performance of the model with all model parameters at the default settings.

5.1 Problem Description

The situation simulated in this exercise is one of the most common problems in business. What happens is that new employees are hired as the backlog of work increases. However, the number of employees hired overshoots the need due to the time lag between the work backlog and employment conditions. When the backlog is finally reduced, there is an excess number of employees (and expenses), relative to the work to be done. As the number of employees is adjusted (by attrition or layoffs) to the new backlog conditions, the cycle repeats itself to some greater or lesser degree. In the meantime, decreasing market prices for work being sold send profitability into the basement.

5.2 Scope

As shown in Figure 2, the exercise simulates the arrival, backlog, processing, and sale of work objects or units. Variable factors affecting the processing of work are shown as circles in the diagram.

The price of work objects sold is fixed at market price, which is a non-controllable variable that decreases over time to half its original value. Profit is calculated both by time period (weekly) and cumulatively over the duration of the simulation as the difference between revenues and expenses.

5.3 Controls

At the start of each model run the user is prompted to enter the following model parameters:

1. Mean Arrival Rate: The arrival of work in units per time period (one week) is determined by an arrival distribution that varies randomly between the mean plus or minus 15%. As work arrives, it goes into the backlog queue and stays there until processed.

2. Hire Threshold: This is the size the backlog must exceed before new employees (New Hires) are hired and placed into the training program.

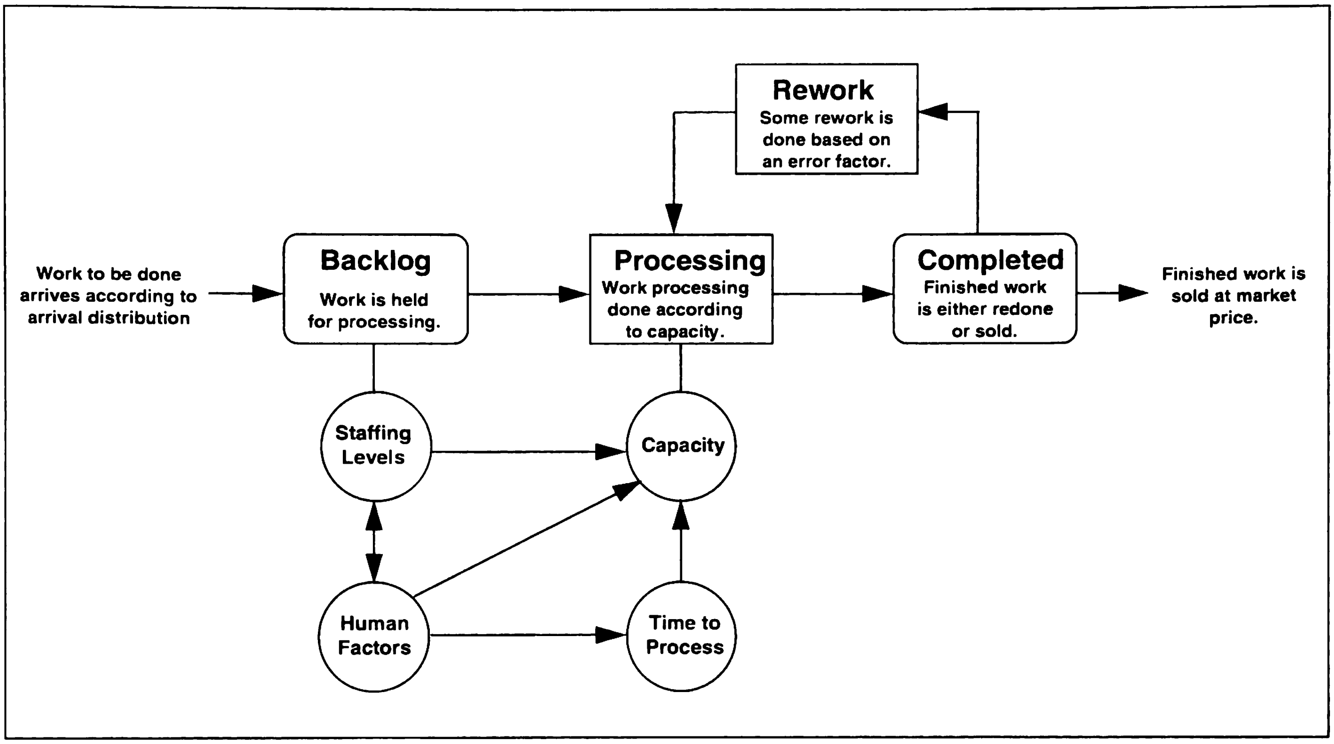

Figure 2: Flowchart of the Business Simulation Exercise

3. Hire Rate: Whenever the Hire Threshold (i.e., work backlog) is exceeded, this variable is the number of New Hires that are brought into the training program.

4. Training Time: This is the number of weeks New Hires spend in the training program. (Note: New Hires also produce work, but at a reduced rate.) Upon completion, of the training time, New Hires become Experts and work at a significantly more efficient rate. Training Time greatly effects efficiency.

5. Time to Process: This is the time (in weeks) that, when all things are equal and perfect, it takes one person to process one unit of work. Unfortunately, all things are not equal and perfect. Decreasing the Time to Process increases the chances for errors and costly rework. Also, human factors, like morale and fatigue, come into play and affect the rate at which work is done.

6. Freeze Level: This is the highest number of employees that will be allowed. Once reached, hiring ceases. As levels of management increase, so do bureaucratic delays to hiring and freezing and sometimes layoffs are needed.

7. Layoff Threshold: Like Freeze Level, this is the absolute ceiling for the number of employees. When this value is reached, layoffs occur. Layoffs diminish morale in relation to the number of people let go. Only trainees are let go.

8. Turnover Rate: This is the percentage of experts that decide to leave the company each time period.

9. Span of Control: This is the highest number of employees that any one manager can manage. Decreasing the Span of Control increases the number of managers, levels of management and bureaucratic delays. Increasing this figure decreases the number of managers but gives them less time to assist in the production of work.

5.4 Human Factors

There are a number of human factors that affect process outcomes which are not directly controllable. These include:

1. Fatigue Factor: Fatigue, which ranges from 0 (no fatigue) to 1 (dead from overwork), is a function of the size of the work backlog. Increases in the Fatigue Factor increase the following factors:

(a) Expert turnover and trainee dropout
(b) Efficiency of work processing
(c) Amount of rework

2. Morale: Morale, which ranges from 1 (highest) to 0 (lowest), diminishes as a function of layoffs and demotions of managers. Decreased morale negatively affects processing time, error rate, dropouts and turnover.

3. Bureaucratic Delays: As the number and levels of managers increase, so does bureaucratic delay, which delays hiring and layoffs.

5.5 Financials

Financial information consists of simple cost and revenue assumptions and comparisons. The following cost items contribute to expenses.

1) Cost per Trainee: This is the loaded, weekly salary of a New Hire.
2) Cost per Expert: This is the loaded, weekly salary of an Expert.
3) Cost per Manager: This is the loaded, weekly salary of a Manager.
4) Training Cost: This is the (weekly) cost of training a new hire.
5) Holding Costs: The simulation assumes there is a holding, inventory or opportunity cost associated with backlogged work.
6) Layoff Costs: This expense simulates a one-time (severance and other benefits) cost of laying off an employee. Dropouts and turnovers do not incur any cost.
7) Rework Expense: Aside from the increased employee cost of handling a work object more than once, there is an additional expense for each reworked object that simulates warranty handling of the work.

5.6 Animation

As the model runs (see Figure 3), the user can see the work backlog increasing and decreasing over time. The model also presents real-time information such as number of reworks, new hires, turnovers and cash flow.

5.7 Reports

Several output reports and graphs provide information on what is happening over the course of the simulation. The most useful of these is a Value History, which plots the value of each model variable over time. To create a Value History, the user simply selects Value History from the View menu of the Output Module, and then chooses which variables to plot. The graph shown in Figure 1, shows the following variables over time:

Work_Backlog_x100
Employees_x100
Price_x10k
Cum_Profit_x1M

6 CONCLUSIONS

As more and more companies come to feel the intense pressure of global competition, Business Process Re-engineering will continue to be a viable option for improving the competitiveness of a business. In order to re-engineer key processes, analysts and managers will turn to modeling tools. Simulation offers advantages over other modeling techniques such as flowcharting and spreadsheet analysis. Simulation models can accurately account for the realities of modern business processes such as variability, uncertainty and interdependencies of resources.

ServiceModel is a simulation tool, ideally suited for modeling business processes. ServiceModel eliminates many of the major obstacles that have prevented simulation from becoming a mainstream process modeling tool by providing a simple, yet powerful interface with other process modeling tools such as flowcharting and CASE tools.

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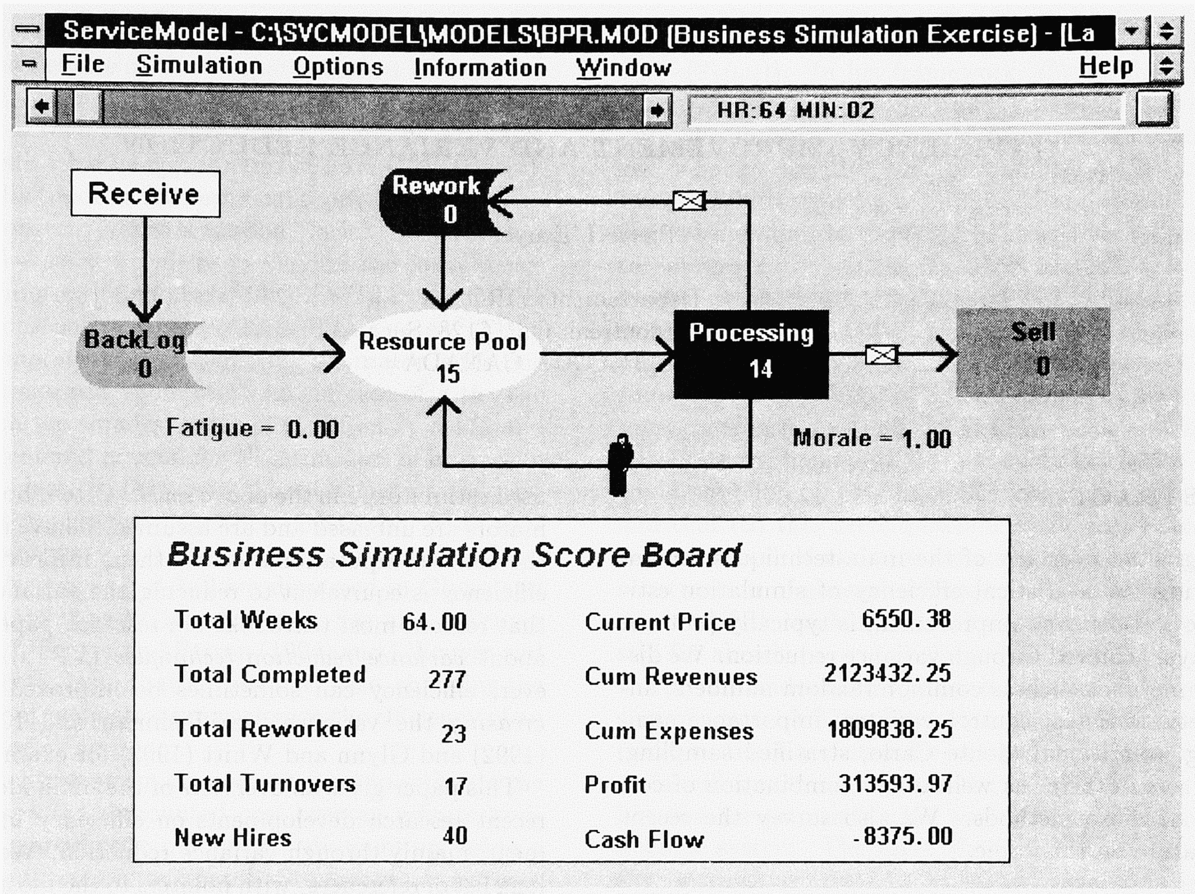

Figure 3: Animation of the Business Process Simulation Exercise

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