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BUSINESS PROCESS SIMULATION

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ABSTRACT

This introductory tutorial provides an overview of business process simulation, describes the modeling and analysis considerations, and lists typical model input, simulation and output requirements. A classification of simulation software products is provided to aid the user in understanding the business process simulation tools. Finally, a simulation exercise is presented to illustrate the power and suitability of simulation for analyzing a business process.

1 INTRODUCTION

The increasing competitive pressure to minimize the time it takes to develop products, bring products to market, fulfill demand, and service customers while maximizing profits has resulted in the fundamental rethinking and redesign of business processes. This has made BPR (Business Process Re-engineering) one of the hottest topics in industry and created a whole new way of doing business.

Re-engineering gurus, Michael Hammer and James Champy, note in their book that only about 30 percent of the re-engineering projects they have seen were successful. One of the primary reasons for this low success rate is that often the analysis behind performance estimates of re-engineered processes have been prepared with flowcharts and spreadsheets. Although flowcharts and spreadsheets are adequate in answering "what" questions, they are inadequate for answering "how", "when", or "where" questions. This has resulted in overly optimistic performance benefits such as cost savings, throughput and service level increases that were promised by BPR.

Business processes are way too complex and dynamic to be understood and analyzed by flowcharting and spreadsheet techniques. Herein lies the opportunity for organizations to institutionalize simulation as the standard tool for BPR because it is the only tool that can provide accurate analysis and visualization of alternatives.

1.1 Business Processes and BPR

Since the focus of this paper is on business process simulation and not on re-engineering, only a brief mention of business processes and re-engineering is provided. For further reading, the reader is encouraged to refer to the books listed at the end of this paper.

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 of the typical examples of business processes are Product Development Processes (Product design, testing, configuration, and documentation), Order Management Processes (Purchasing, receiving, storage, materials management), Financial Management Processes (Payroll, audit, accounts receivable, accounts payable), Information Management Processes (Database management, networking, client-server applications), and Human Resources 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.

1.2 Why Simulate Business Processes?

Typically, a BPR project begins with the end in mind where the end goal is to achieve one or all of the following objectives:

- increase service level
- reduce total process cycle time
- increase throughput
- reduce waiting time

- reduce activity cost
- reduce inventory costs

Mark Youngblood, in his book titled "Eating the Chocolate Elephant", lists 32 ways to achieve these objectives. Most of the principles are fundamentals of Industrial Engineering that have been applied in manufacturing industries for decades. It is worthwhile to mention some of them because they are the principles that are usually applied to re-engineering business processes.

- Combine duplicate activities
- Eliminate multiple reviews and approvals
- Reduce batch sizes
- Process in parallel
- Implement demand pull
- Outsource inefficient activities
- Eliminate movement of work
- Organize multi-functional teams

These principles clearly offer answers to the question of "What needs to be done?" to achieve the desired BPR objectives. But, re-engineering business processes involves changes in people, processes and technology over time. The key word here is "over time". The interactions of people with processes and technology over time result in an infinite number of scenarios and outcomes that are impossible to comprehend and evaluate without the help of a computer simulation model. This is where simulation provides the greatest value for achieving BPR objectives. By tweeking decision variables in a model without the cost and risk of disrupting existing operations or building a new system, one can accurately predict, compare, or optimize the performance of the re-engineered process.

For example, the BPR professionals, who are designing the customer service process for a call center, must understand the random nature of calls arriving at the center, the random nature of processing times, the interdepencies between customer representatives, the alternative routing schemes and capture the dynamic nature of these behavior in a model. If the performance goal is to achieve 100 percent service level or eliminate customer waiting times, a simulation of the process is absolutely necessary to accurately determine staffing requirements, telecommunications technology requirements, and how services are provided to the callers.

1.3 What is Business Process Simulation?

Process simulation is the technique that allows representation of processes, people, and technology in a dynamic computer model. There are essentially four steps in doing business process simulation. They are: 1) building a model, 2) running a model, 3) analyzing the performance measures, and 4) evaluating alternative scenarios. A model, when simulated, mimics the operations of the business. This is accomplished by stepping through the events in compressed time while displaying an animated picture of the flow. Because simulation software keeps track of statistics about model elements, performance of a process can be evaluated by analyzing the model output data.

There is much more to conducting a successful simulation study than the four steps mentioned above. Therefore, the readers new to simulation are encouraged to review the simulation literature and receive proper training before taking on major business process simulation projects.

2. MODELING ELEMENTS

Even though model building constructs may have different names or characteristics in different products, most business process simulation models contain some basic building blocks, activity modeling constructs, and advanced modeling elements. In this section, an overview of these modeling elements are presented.

2.1 Basic Model Building Blocks

The four basic building blocks of a process model are flow objects, resources, activities, and routings.

Flow objects: Otherwise referred to as entities, tokens or transactions, these are the objects that are processed by resources. Examples of flow objects are customers, products, documents, orders, and calls. Entities may have attributes such as order quantity, priority, and due date.

Resources: These are the agents that are used for adding value to flow objects. Examples of resources are service representatives, automated process equipment, and transportation equipment. Resources are allocated to activities and may have attributes such as rate, expertise level, and shifts.

Activities: Activities are connected by routings to represent the flow of objects through the simulation model. Activities may be value added or non-value added. Examples of value added activities are assembly, batching, and transportation. Examples of non-value added activities are queuing, blocking, and downtime. Activities may have attributes such as time, cost, and capacity.

Routings: Routings define the various types of connections between activities. Flow objects follow the routings as they are processed by the model throughout the simulation. Flow objects are routed between activities based on deterministic, probabilistic or conditional routings.

2.2 Activity Modeling Constructs

A minimum set of activity modeling constructs are needed for modeling the dynamic behavior of business processes. These activity modeling constructs enable modeling arrivals, queuing, branching, assembly, disassembly, batching, unbatching, and cloning.

Creation: A creation activity generates the arrival of entities into the model. Arrivals may be random, deterministic or conditional. An example of a creation activity is the arrival of patients in a clinic. A creation activity may have values for arrival time, quantity, frequency and occurrences.

Queuing: Flow objects may be held up in a queue waiting for a resource or for a signal. Queuing rules such as FIFO, LIFO, etc. are important for sequencing entities waiting in a queue.

Branching: A branching activity allows for defining alternative routings for flow objects. Branching may be based on a probability or a condition. For example, the outcome of an inspection operation may be modeled using probabilistic branching.

Assembly: An assembly activity assembles multiple entities coming from multiple sources to create a single entity. For example, the development of a business proposal may contain three documents that are merged using an assembly activity.

Disassembly: A disassembly activity performs the opposite operation that an assembly does. It takes a single entity and disassembles it into its components. For example, disassembling a computer into its components for repair may be modeled using a disassembly activity.

Batching: A batching activity combines a given quantity of entities into a single batch. A batch may be defined as a permanent or a temporary batch. An example of a batching activity is the accumulation of mail for delivery.

Unbatching: An unbatching activity splits a single entity into individual entities. For example, unloading of a truck that results in multiple loads may be modeled with an unbatch activity.

Cloning: A cloning activity makes multiple copies of the original entity. For example, if a document is being edited in a groupware software that results in multiple copies of a file, this activity may be modeled using a cloning construct.

2.3 Advanced Modeling Functions

In addition to basic building blocks and activity modeling constructs, users may need to have access to more advanced modeling functions that provide the power and flexibility to deal with the complexity of real world business processes. Some of these functions are variables, attributes, decision logic, resources schedules, interruptions, and user defined distributions.

Variables: Variables are logical values that may be used for decision making or performance tracking. Once you define a variable, a simulation model automatically keeps track of its values over time. For example, the capacity or trigger level for an activity may be a logical variable that is used for decision making in an IF-THEN statement.

Attributes: Flow objects may have distinct characteristics such as time or cost. For example, you may define orders as entities that arrive in the system where the order quantity would be an attribute that is different from one order to another.

Decision logic: In order to define complex routing or resource assignment rules, programming-like statements such as IF THEN ELSE, INCREMENT, and DECREMENT are needed. These statements provide the flexibility to model unique, real-world situations.

Resource Schedules: Since the activities are constrained by the availability of resources, assuming that all resources are available throughout a simulation is unrealistic. Resource schedules allow a realistic way to define the times when resources are available to work and when they are off shift.

Interruptions: Most business processes experience interruptions that may be planned or unplanned. Because of the non-linear impact of interruptions on processing, represention of these situations provide a more accurate picture of the performance measures of a business.

User defined distributions and functions: User distributions or functions may be used for representing the variability associated with arrival times, activity times, or move times. User distributions may be discrete or continuous.

3 MODELING, PROCEDURE, AND ANALYSIS CONSIDERATIONS

Simulation models can provide the most accurate and insightful means to analyze and predict the performance measures of business processes. However, one must be aware of the dangers of using incorrect modeling and analysis procedures which can result in erroneous results. In this section, business processes are classified into 4 major categories to discuss the unique modeling, simulation procedure and analysis considerations. They are:

1. Project-based processes,
2. Production-based processes,
3. Distribution-based processes,
4. Customer service based processes.

This classification is not intended to imply that all business processes fall clearly into one of these four types. In fact, they do not. For example, a customer service process may have both front-room and back-room activities where the front-room activity is a customer service based process while the back-room activity is a production-based process. Nevertheless, the considerations presented in this section should prepare the user for planning a business process simulation study. They might also be helpful for assessing the suitability of a particular simulation software for that application.

3.1 Project-based Processes

These processes are usually provided by a single person or a group of people. Typical examples are product development processes and administrative processes. Usually, project-based processes are analyzed using project management tools. However, process cycle times and resource requirements analyzed by simulation techniques are more accurate because activity times are highly variable and shared resources create multiple interdependencies.

Modeling priorities, pre-emption, shifts, downtime, overtime, learning curves for resources are some of the important considerations in building a valid simulation of a project.

Model Elements	Examples
Flow objects	proposal, report
Resources	consultants, workers
Activities	design, testing, review
Routings	parallel flow, feedback loops

Table 1: Examples For Project-based Processes

One of the important procedure and analysis considerations regarding the simulation of a project is multiple replications. Since activity times are highly variable, a single simulation run will produce only a single observation. Multiple replications will produce several observations which will provide a more accurate estimate and confidence interval for the performance measures.

3.2 Production-based Processes

In production-based processes, outputs are produced in a batch or continuous flow mode in relatively high volumes. Typical examples are order fulfillment, accounts payable, and claims processing processes.

Activities such as batching, unbatching, assembly, disassembly, setup, inspection, and rework are typical activities in production-based processes. In order to accurately model these activities, a model must allow for keeping track of individual flow objects and their attributes. Other important modeling consideration with production based processes are queuing rules and downtime modeling.

Model Elements	Examples
Flow objects	orders, electronic forms
Resources	equipment, staff
Activities	batching, assembly, inspection
Routings	sequential flow, feedback loops

Table 2: Examples For Production-based Processes

Production-based process models are usually simulated to obtain steady-state behavior since a repeating sequence of products is always being produced. An important procedural concept in analyzing performance is determination of warm-up period and elimination of bias associated with statistics collected during warm-up.

3.3 Distribution-based Processes

Distribution-based processes include transportation and delivery processes where products or people are carried between locations via a distribution network. A fundamental difference between transportation and delivery is that the flow objects being transported are people rather than goods. Typical transportation processes are found in mass transit systems. Typical delivery processes are found in manufacturing distribution, mail delivery and moving services.

Since distribution-based processes require mobile resources to move flow objects between pickup and delivery points, it is important to define the path networks and movement characteristics for these resources. It may sometimes be more appropriate to model transportation resources are flow objects. When modeling distribution processes, it is important to define attributes for flow objects in order to keep track of unique characteristics such as destination, size, or cost.

Model Elements	Examples
Flow objects	People, loads
Resources	Trucks, rail cars, planes
Activities	Load, move, unload
Routings	on predefined networks

Table 3: Examples For Distribution-based processes

Most distribution processes are transient in behavior. Therefore, simulation period should be long enough to

3. 4 Customer Service-based Processes

The customer service-based processes present a major area of application for simulation because total waiting time may be as high as ninety five percent of the total processing time in a typical service process. Typical customer service processes are telephonic services (call centers), service factories (restaurants, copy centers), service shops (hospitals, repair shops), and retail stores.

Simulation of customer service processes present a unique challenge because both the flow objects and resources are humans. Humans have much more complex and unpredictable behavior than products, documents, equipment, or vehicles. For example, customers waiting in a line may balk, jockey, or reneg. Modeling these types of situations require programming logic to realistically represent the behavior. Resource interactions with flow objects also create situations where resources may change their behavior based on states of the flow objects. Once again, programming flexibility may be required to model such situations. Usually, service activities times are highly variable and customer arrivals are random. Therefore, the use of probability distributions are required for accurate representations.

Because arrivals are cyclical and random, customer 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. Because activity times and costs are highly variable, it is important to run multiple replications of a model for statistically valid analysis of model results.

Model Elements	Examples
Flow objects	customers, patients
Resources	service representative, nurse
Activities	take order, service, assist
Routings	based on customer type or state

Table 4: Examples For Customer Service Processes

4 SIMULATION TOOLS

In the past few years, several new software tools have been developed specifically for modeling business processes. 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.

Business Process Simulation software tools can be broken into three major categories:

1) Flow Diagramming Based Simulation Tools: At the most basic level are flow diagramming tools that help define activities and routings. Flowchart based models are methodology independent therefore they are the easiest to learn. Unfortunately, the ease-of-use results in limited modeling capability and simulation analysis capability. Examples of flow charting based simulation tools are Process Charter and Optima.

2) System Dynamics Based Simulation Tools: At the next level are continuous simulation software products that utilize the systems dynamics methodology. Models built with these tools consist of methodology specific constructs such as levels, stacks, flows, converters and connectors. Examples of these tools are Ithink and Powersim.

3) Discrete-event Based Simulation Tools: The most capable and powerful tools for business process simulation are the discrete-event driven simulation products. These tools provide modeling of entity flows with animation capabilities that allow the user to see how flow objects are routed through the system. Some of these tools even provide object-oriented and hierarchical modeling which simplifies development of large business process models. Examples of discrete-event based simulation tools are BPSimulator, Extend+BPR, ServiceModel, and SIMPROCESS.

5 A BUSINESS SIMULATION EXERCISE

During the presentation of this paper at the Winter Simulation Conference '95, a presentation of a typical business simulation exercise will be shown. In this section, a brief description of the exercise is provided. The exercise is taken from the book titled "Reengineering the Corporation" based on the example about IBM Credit Corporation. A flow diagram of this exercise is shown in Figure 1.

5.1 Model Description

A call from a field salesperson requesting a credit issuance quote for a client is logged. It is processed by a credit specialist who checks the client's credit worthiness. Next, a business practices specialist modifies the terms of the standard loan agreement. A pricer then determines an appropriate interest rate to charge. Finally, an administrator prepares a quote letter which is delivered to the field representative.

In the re-engineered business process, a generalist, or a deal structurer logs the request and determines the degree of a difficulty of the deal. If it is simple, the generalist proceeds to complete the rest of the steps with the assistance of an information system. If the deal is complex, the generalist assembles a deal-structuring team from a small pool of specialists. The team then completes the deal.

6 CONCLUSIONS

Business processes are too complex and dynamic to be analyzed with flowcharting and spreadsheet analysis. Discrete event simulation is the most powerful and realistic tool for analyzing the performance of business processes. Simulation takes into account the variability of activity times, interdependencies of resources, and other complexities that affect performance over time. Discrete event based simulation tools provide statistical input and output capabilities and advanced modeling elements that are necessary to accurately simulate business processes.

As the awareness and education for discrete event simulation grows and simulation software products reach to mainstream users, simulation, just like spreadsheets and flowcharts, will be institutionalized by organizations and even by consumers.

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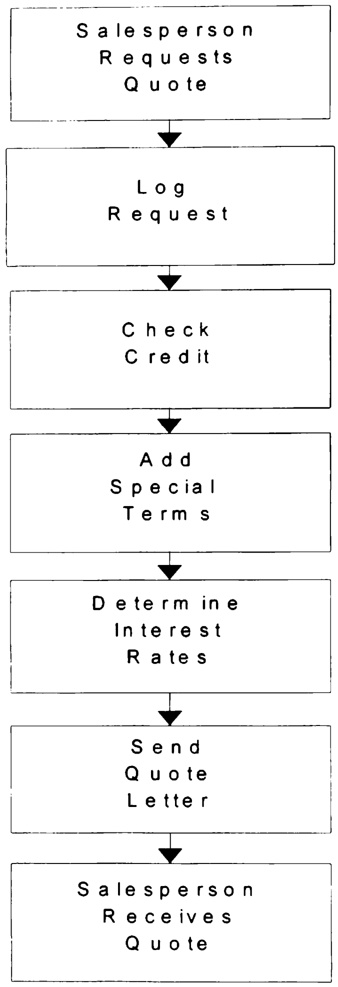

Figure 1: Flow Diagram of the Simulation Exercise