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BUSINESS PROCESS SIMULATION

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ABSTRACT

This introductory tutorial provides an overview of business process simulation and how it works. Descriptions of modeling elements and model performance measures are presented. Classification of business processes is followed by unique modeling, simulation procedure and analysis considerations. Types of business process simulation tools are discussed. Finally, a purchasing process simulation exercise is presented to illustrate the power and suitability of simulation for analyzing a business process.

1 INTRODUCTION

Industrial and service enterprises are faced with increasing pressures to minimize the time it takes to service customers, develop products and fulfill demand. A business manager's ability to minimize risks while maximizing profits depends on his ability to quickly evaluate alternatives. Whether the alternatives involve automation or outsourcing of a process, expansion or downsizing of the workforce, businesses must be able to evaluate the impact of change with accuracy and speed.

Understanding and estimating the time and cost to complete a product development process is a key business challenge. Typically, managers have relied on project management tools to planning purposes. However, highly variable activity times and interdependencies between resources make it very difficult analyze activity costs and resource requirements using traditional project management tools.

Today, customers are much more demanding and cost-conscious. Such performance metrics as waiting time and activity costs are critical to providing quality service at competitive prices. Typically, staffing and pricing decisions for a customer service process have been made by analytical tools which fail to take into account the randomness and system dynamics that result in queuing and variable costs.

For an industrial enterprise, the key problem in supply chain management is how to balance inventory. Variability in demand and process times, complexity of the supply chain, and system dynamics create uncertainty that can not accurately be modeled and analyzed with spreadsheets and flowcharts.

The power of computer simulation combined with simplicity of flowcharting and spreadsheets provides the most cost effective, accurate, and rapid strategic weapon for businesses to evaluate alternatives prior to committing expensive resources and time. The ability to visualize how a process would behave, measure its performance, and try "what ifs" in a computer model makes computer simulation an invaluable tool for decision making.

Like activity-based costing (ABC), business process simulation (BPS) embodies the concept that a business is a series of inter-related processes, and that these processes consist of activities that convert inputs to outputs. A BPS model realistically captures the resource constraints, decision rules, and stochastic behavior of real-world situations. A process 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 workflow. Because simulation software keeps track of statistics about model elements, performance of a process can be evaluated by analyzing the model output data.

2 HOW BPS WORKS

Creating a process model starts with mapping the business processes. Most process modeling tools provide a drag and drop type of a graphical interface with process documentation facilities. Then, you drill-down into the processes where sub-processes and activities are defined. Describing the entities that flow through the processes and linking the processes using connectors facilitates the workflow definition. Finally, you define

the resources and assign them to the activities where they are used.

Before simulating a model, you need to select the performance measures of interest. For example, you may be interested in throughput and cycle time reports for entities, activity costs for processes, and utilization reports for resources. When you run a simulation, the process simulation tool automatically verifies your model and begins advancing the simulation clock. During the simulation, you see an animated picture of the flow that helps you visualize the process in motion. You can also have BPS generate real-time graphs, letting you view key performance measures, during the simulation.

When the simulation is over, you can bring up the model results and analyze the performance measures of interest. To draw useful and correct conclusions from simulation results requires statistical input and output data analysis. Questions such as which distribution to use for representing activity times or how many data points to collect are important is developing a statistically valid model. And, questions such as how long to simulate a process or how many replications to run become significant for producing valid and accurate results.

The strength of process simulation is in its ability to incorporate stochastic situations in the model. It cannot offer an optimum solution. In order to find the best solution, one has to determine various scenarios and simulate them. This is where Design of Experiments can aid in searching and finding the best solution. With the aid of Design of Experiments, one can also compare the performance measures from Current State with measures from Future State alternatives.

3 MODELING ELEMENTS AND MODEL PERFORMANCE MEASURES

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.

3.1 Basic Model Building Blocks

The four basic building blocks of a process model are entities, resources, activities, and connectors.

Entities: Otherwise referred to as flow objects, tokens or transactions, these are the objects that are processed by resources. Examples of entities 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 Entities. Examples of resources are service representatives, automated process equipment, and transportation equipment. Human resources can be defined as members of departments and workgroups. Resources are allocated to activities and may have attributes such as cost and expertise level.

Activities: Activities are linked by connectors to represent the flow of entities through the simulation model. Activities may be value added or non-value added. Examples of activities are branching, assembly, batching.

Connectors: Connectors are used for linking processes and activities. Entities follow the connectors as they are processed by the model. Connectors are helpful for defining parallel flows and rework situations based on deterministic, probabilistic, or conditional decision rules.

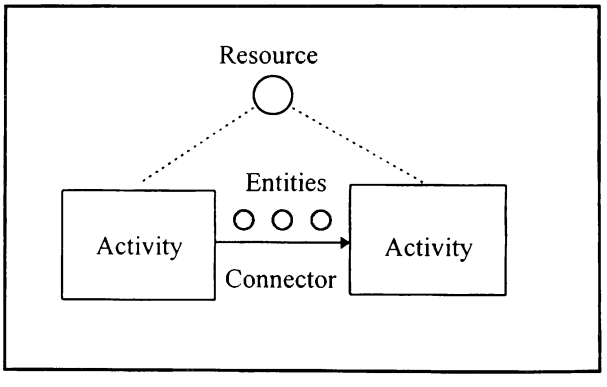

Figure 1: Basic Model Building Blocks

3.2 Activity Modeling Constructs

A minimum set of activity modeling constructs are needed for modeling the dynamic behavior of business processes. Examples of activity modeling constructs include generate, branch, assemble, batch, gate, split, and join.

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

Branch: A BRANCH activity allows for defining alternative routings for Entities. Branching may be based on a probability or a condition. For example, the

outcome of an inspection process may be modeled using probabilistic branching.

Assemble: An ASSEMBLE 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.

Batch: A BATCH 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.

Gate: A GATE activity holds entities in a queue, until a signal is received. For example, a GATE activity would be used to model orders held in inventory until a signal is received is from the distributor to fulfill the demand.

Split: A SPLIT activity takes an incoming entity and creates children of that entity as well as providing an output of the parent entity. For example, copies of a purchase order may be created with a SPLIT activity and sent to accounts payable and shipping.

Join: A JOIN activity takes the children and parent entities that were split up, and matches them to produce the original one. For example, a JOIN activity may be used for matching the paperwork with the shipment.

3.3 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 attributes, expressions, resources schedules, interruptions, and user defined distributions.

Attributes: Attributes are logical values that may be used for decision making or performance tracking. For example, the capacity or trigger level for an activity may be an attribute that is used for decision making in an IF-THEN statement. Entities 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.

Expressions: In order to define complex decisions 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, representation 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.

3.4 Model Performance Measures

Basic model performance measures are cycle time, entity count, resource utilization, and activity cost.

Cycle Time: Cycle time is the total time an entity spends traversing a process. This means cycle time includes value-added process time, waiting time, movement time, etc. One of the most valuable outputs of BPS is the automatic tracking and calculation of cycle time for each entity. Furthermore, BPS tools provide average and maximum values based on the total count of entities that traversed the process.

Entity Count: Entity counts include the total number of entities that traverse a process or that are still being processes. This means that the total entity count is the sum of entities processed plus the entities that are in-process. Once again, BPS tools automatically track and calculate entity counts for each type of entity in a model.

Resource Utilization: During a simulation, resources change states from busy to idle, from unavailable to reserved. Resource utilization defines the percentage of time that a resource spends in each state. The availability and assignment of resources dictate the allocation of resources to activities in a model. So, the resource utilization results provide useful statistics in measuring and analyzing under-utilization or over-utilization of resources.

Activity Cost: When a resource is defined in a process model, it is defined by the number of available units, usage costs, setup costs, and fixed costs. When an activity is defined, it is defined by the resources required to perform it, the duration for the activity, and the entities that it processes. During a simulation, the BPS tool automatically keeps track of the time each entity spends in an activity and the time each resource is assigned to that activity. Activity cost calculations provide a realistic way for measuring and analyzing the costs of activities. Object-oriented BPS tools allow detail breakdown of activity costs by resource or entity type as well as aggregated process costs.

Advanced model performance measures are measures that need to be customized using advanced modeling elements such as attributes and expressions. Examples are service level, on-time performance level, inventory level, and order fill rate.

4 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.

4.1 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, preemption, shifts, downtime, overtime, learning curves for resources are some of the important considerations in building a valid simulation of a project.

Model Elements	Examples
Entities	proposal, report
Resources	consultants, workers
Activities	design, testing, review
Workflow	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.

4.2 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 Entities and their attributes. Other important modeling consideration with production based processes are queuing rules and downtime modeling.

Model Elements	Examples
Entities	orders, electronic forms
Resources	equipment, staff
Activities	batching, assembly, inspection
Workflow	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.

4.3 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 Entities 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.

When modeling distribution processes, it is important to define attributes for Entities in order to keep track of unique characteristics such as destination, size, or cost. When modeling movement, it may sometimes be more appropriate to represent transportation resources as entities.

Model Elements	Examples
Entities	people, loads
Resources	trucks, rail cars, planes
Activities	load, move, unload
Workflow	alternative routes, looping

Table 3: Examples For Distribution-based processes

Most distribution processes are transient in behavior. Therefore, simulation period should be long enough to include a cycle period and multiple replications should be made to analyze the performance measures.

4. 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 entities 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 renege. Modeling these types of situations require programming logic to realistically represent the behavior. Resource interactions with entities also create situations where resources may change their behavior based on states of the entities. 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

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

Table 4: Examples For Customer Service Processes

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.

5 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 four major categories:

1) Flow Diagramming Based BPS 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 ProcessModel.

2) System Dynamics Based BPS 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 BPS Tools: Discrete-event based simulation tools are more powerful that flow charting tools. They are also better suited for modeling business processes as compared to system dynamics based tools. These tools provide modeling of entity flows with animation capabilities that allow the user to see how entities are routed through the system.

Examples are Extend BPR, BPSimulator, and ServiceModel.

4) Object-Oriented, Discrete-event Based BPS Tools: The most capable and powerful tools for business process simulation are the object-oriented, discrete-event driven simulation products. These tools provide object-oriented and hierarchical modeling which facilitates the development of enterprise process models through the use of reusable templates. Examples of object-oriented, discrete-event based simulation tools are SimProcess and Rethink.

6 A PURCHASING PROCESS SIMULATION

During the presentation of this paper at the Winter Simulation Conference '96, a presentation of a typical business simulation exercise will be shown. In this section, a brief description of the exercise is provided.

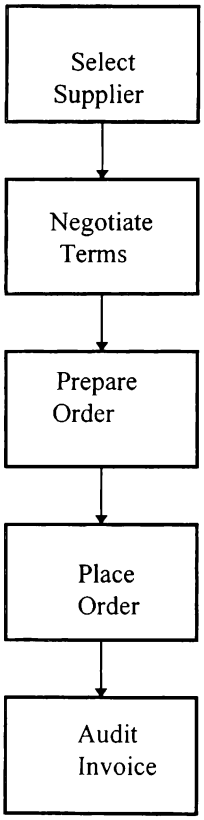

Figure 2: Purchasing Process Flow Diagram

This purchasing process simulation example presents three alternatives ways for organizing resources. The purpose of the exercise is to determine the best organization.

Alternative 1: The purchasing process is performed by centralized, functional organization where the five functions are performed by staff dedicated to each function.

Alternative 2: The purchasing process is performed by three decentralized, product organizations where the each product organization performs all 5 functions for its product line.

Alternative 3: The purchasing process is performed by a hybrid organization where the supplier selection and terms and pricing functions are performed by a centralized organization; and the other 3 functions are performed by decentralized, product organizations.

7 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.

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