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SYSTEM SIZING USING MODELING AND SIMULATION

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ABSTRACT

A set of well-honed procedures have evolved for developing models that realistically reflect the user's application area. The benefits derived from the application of this systematic approach begin to accrue almost immediately. This paper will address the benefits derived from the application of modeling and simulation to areas such as architectural trade-offs, and sizing the system to meet the workload. A variety of practical examples will be included from server systems, telecommunications networks and manual processes. Inherent in the successful application of the modeling and simulation procedures is the requirement that they be applied iteratively and in a manner that produces frequent feedback from the system designers, managers and user community.

1 INTRODUCTION

The procedures developed over time for applying modeling and simulation to architectural trade-offs and system sizing are summarized in the Figure 1 Gantt Chart. The generic phases of the process appear in sequence along with a conceptual time line.

The first phase, Detailed STATIC Model, involves the development of a spreadsheet-based model of the system, network or process. The STATIC Model plays a role throughout the modeling and simulation process. Initially it serves as a repository for the average values of variables, for constants and for key relationships that govern the application. Although limited by the deterministic nature of these formulas, the spreadsheet-based STATIC Model

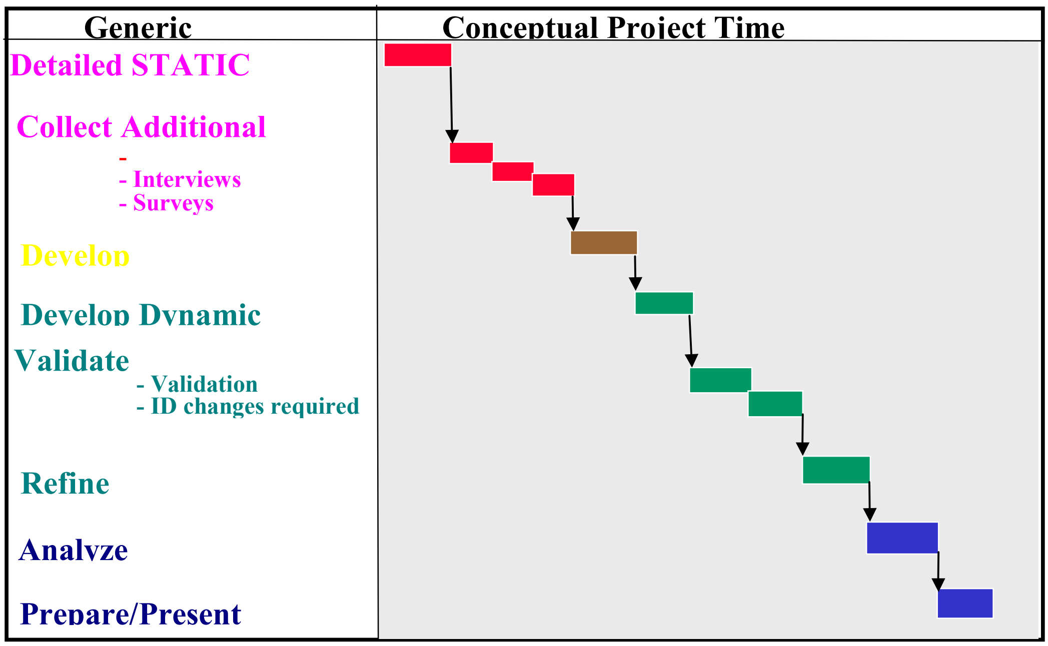

Figure 1: Process for Applying Modeling and Simulation to Sizing a System

can be used to gain some initial insight in to the fundamental operating characteristics of the system, network or process. The STATIC Model typically increases in detail and value throughout the modeling process in direct proportion to the additional information collected.

This Additional Information is acquired from workshops, interviews, surveys, time-and-motion studies, and from frequent feedback from the user on preliminary model results.

The Development of the Architecture not only benefits from the trade-off analyses possible with a model, but is essential for the detail required for simulation.

The DYNAMIC (discrete event simulation) Model consists of innumerable software representations of the process sequences, process delays, queues and logic embodied in the STATIC Model. Stochastic variation is introduced by replacing the average values used for variables in the STATIC Model with statistical functions. This dramatically increases the degree of realism in the results.

Model Validation and Refinement are important phases and ones that equally involve the STATIC Model. The Preparation and Presentation of Results involves taking the voluminous tabular output of a model and distilling it down to the salient points user can easily comprehend. This is a major challenge and one that requires the extensive use of graphics.

The activities described in the above phases take place iteratively and therefore constitute the modeling cycle illustrated in Figure 2. This cycle provides on-going analysis, gradual model enhancement, and frequent feedback from the presentation of preliminary results to the user. Model Tool Selection occurs only in the first iteration.

2 MODELING BENEFITS

2.1 Benefits Prior to System Sizing

A benefit realized early in the modeling cycle and well before a model is constructed is the summary documentation and work flow graphics prepared for use by the modeler. Although these are byproducts of the modeling process, they often provide the operational manager and the manager's staff with valuable up-to-date details on today's operation. The system loading for each hour of the day depicted in Figure 3 is an example of this type of valuable information compiled well before a model was developed. Along the floor of this 3-D plot is depicted the loading on local servers around the world. Along the back wall is depicted the worldwide composite loading on the central server site. The maximum points indicate when during the day network modifications should be temporarily halted, and the minimum points indicate when resource-intensive activities, such as downloads, should be scheduled. Another benefit realized early in the cycle and closely coupled to process documentation, is an up-to-date set of operational metrics. These quantitative factors are typically compiled from existing presentations, statistical reports and from databases. They are also based on interviews with user personnel, on observations of the existing process, on observations of similar processes elsewhere, and on statistical data gathered while observing the actual operation. These metrics provide customer

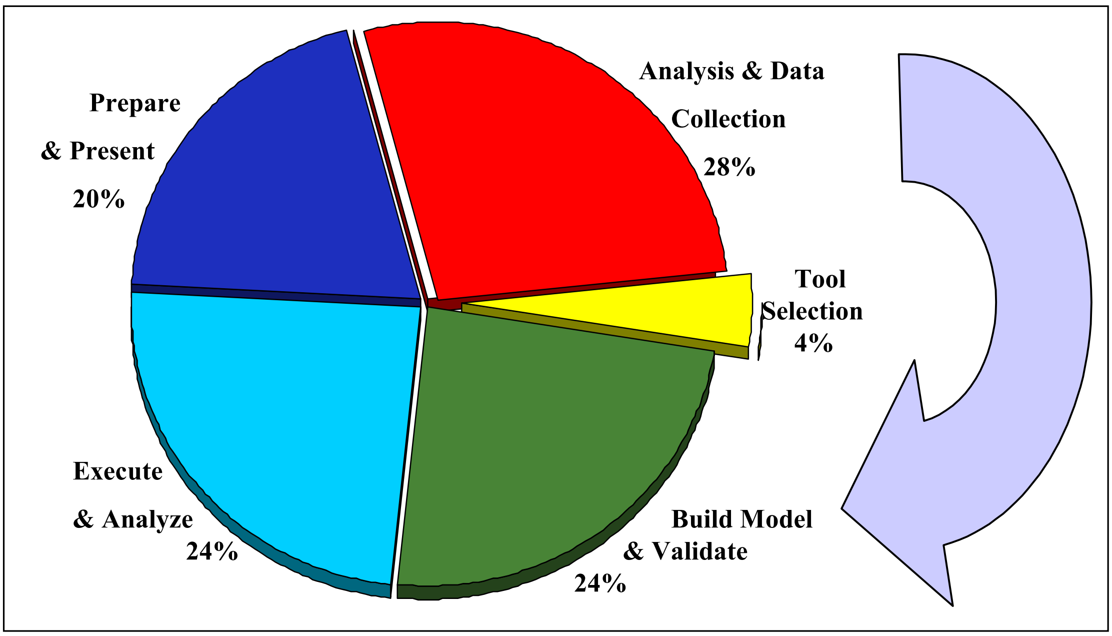

Figure 2: Iterative Approach to Applying the Modeling Process to Maximize Feedback from User

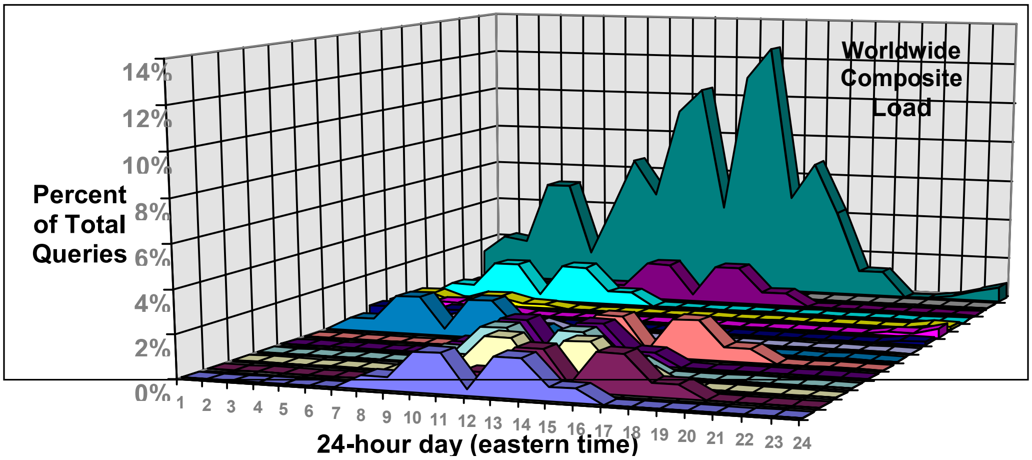

Figure 3: Valuable Operational Metrics Compiled Prior to the Development of a Model

management with insight on the operating characteristics of selected critical process steps. In early iterations of the modeling cycle they provide the average values of the primary variables, the constants, and the key mathematical relationships that underlie the process. In later iterations of the modeling cycle they provide the frequency distributions that make the behavior of the simulation model so realistic.

2.1.1 Benefits of System Sizing with Simulation

Few processes in today's technology are simple and straightforward. End-to-end performance is a function of the combined result of numerous individual processing steps in series and parallel so that the designer can not intuitively envision how a change to a component process will effect overall performance. This type of complex process is illustrated in Figure 4 where each of 38 pages consisted of numerous processing steps. How could the impact on overall performance possible be envisioned from shifting the balance of resources on page 11 of 38.

One approach to gaining some insight on overall performance is to construct a prototype in the lab that is a microcosm of the entire system or network. Although the performance metrics produced by a prototype are extremely valuable, this is an extremely costly option. In addition, there are limits to how well a prototype in the lab can represent the system or network under full load. Figure 5 is a LAN network configuration depicting hundreds of servers interconnected by a switched backbone. Although a prototype can provide valuable operating metrics, no prototype or pre-production test could verify the architecture and design of a configuration of this size and complexity. Predicting the performance of this system under full load was possible only through the application of modeling and simulation.

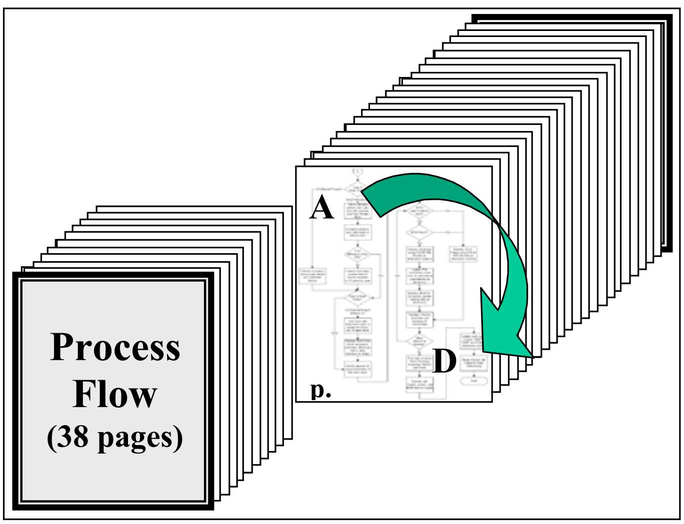

Figure 4: Effect on Overall Performance of Shifting Resources Among Tasks Is Not Intuitive

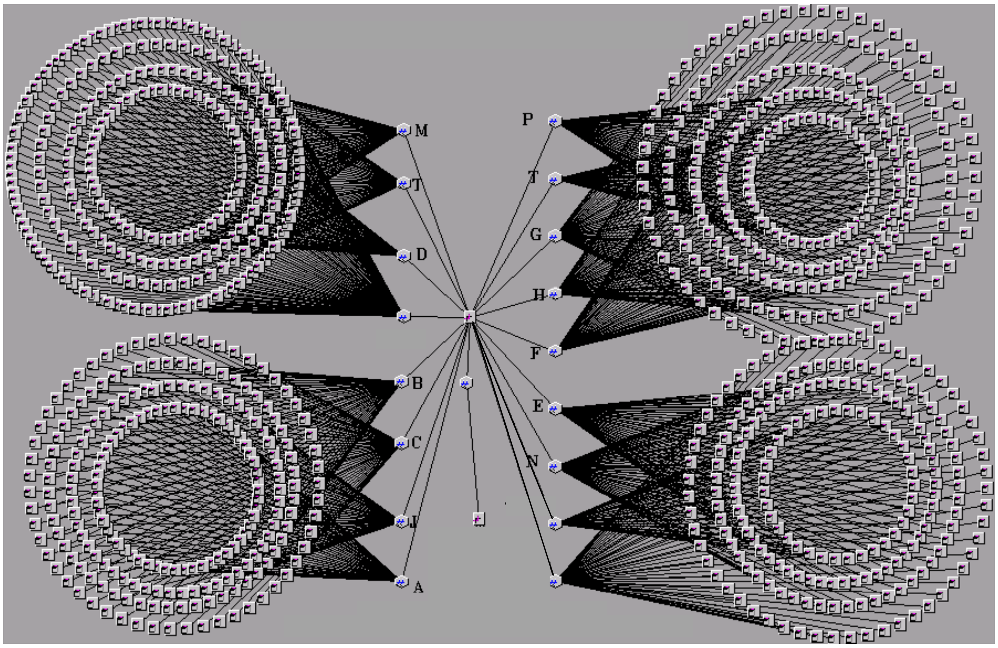

Figure 5: LAN Network Configurations Interconnected by a Switched Backbone

The results of an early, high-level version of the processing model can be valuable in identifying processes that are saturated and resources that are underutilized. It is often at this point in the modeling process that the designer learns that some independent variables believed to be critical are inconsequential, while other variables believed to be insignificant, were actually major determinants.

Process simulation provides the manager with realistic results by introducing the effect of randomness in each process step. Statistics gathered in the analysis phase are incorporated in the model to reflect:

- variations in the rate of the arrival of work entities such as documents or packets.
- variations in the difficulty level of the arriving work entities such as the manual operation of removing a staple from input documents when only a portion of the documents are stapled together.
- variations in the size of the arriving work entities such as short control packets versus long information packets.
- variations in an equipment operator's document handling rates based on factors such as agility, experience and degree of training.
- variations in the throughput rates of document-handling equipment such as the degree of training the operator has received or how recent adjustments had been made to the equipment in use.

For major systems, networks or processes, the combined effect on processing time and processing cost of these innumerable variations can only be observed using modeling and simulation.

The model can be employed to examine the effect changes in independent variables (e.g., staff size), would have on dependent variables (e.g., processing delay).

Process design tradeoff analyses can be conducted to observe the effect on overall operating cost and processing time of one work flow alternative versus another. When employed in this manner, modeling results can also dramatically reduce the time lost to disputes within the organization over competing operational approaches.

The model becomes a valuable budgeting tool by enabling the manager to demonstrate to the chain of command the effect on throughput and performance of budget-cutting measures under consideration.

With the model in place, sensitivity analyses can be conducted at a small incremental cost. For example, the sensitivity of system size to variations in the processing completion date can be explored.

In many cases the model will be the best available representation of the proposed operation. This makes it a valuable tool for use in Verification & Validation (IV&V) of initial test results.

2.2 Benefits Following System Sizing

Users can capitalize on the investment in the model by employing the tool in various technical roles and management roles long after the design and system-sizing phase of a program.

One follow-on technical role for the model is to provide benchmarks for systems testing or integration testing. In this case, the model is executed using an input file that reflects the test input data instead of the expected total system workload. In this role the model provides the values of the system performance parameters and throughput that the testing organization should expect to be observed during the test.

Another follow-on role for the model is as a tool for management. First, it can be used to identify specific risks such as delay in the transition from the legacy system, the failure of a key processor, communications congestion or an excessive backlog at a manual process. Next, it can be used to assess the potential impact from the occurrence of these impediments, and the likelihood of their occurrence. This will enable management to compute their potential cost and prioritize the identified risks. Finally, it can be employed to analyze the effectiveness and cost of competing risk mitigation strategies such as the use of backup equipment or alternately-routed backbone circuits.

Once the system is running, the model can be a valuable tool of the operational manager. It can be used by the quality assurance staff and can be used to determine the best operational approach when the following scenarios occur:

- Evaluation of alternative levels of workload and variations in the workload over time.
- Scheduling of shifts based on the optimum combination of manpower versus equipment.
- Cost justification for the introduction of new technology such as multiprocessor servers.

As outlined above, modeling an simulation have broad application to system sizing including to technical and management activities that precede and follow system sizing.

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