Motivated by technological innovation and increasingly competitive markets, U S WEST Communications has been reengineering its core service processes to improve customer loyalty, cost effectiveness, and efficiency of services. The operations research modeling group at U S WEST Advanced Technologies has developed a service process simulation model that identifies where and when process reengineering efforts should occur. In a successful implementation, we analyzed the quantitative impact of changes in key process parameters, such as the error rate and staffing level of the service center, in the metropolitan area of Minneapolis and St. Paul. U S WEST is deploying an outgrowth of this process modeling to support process reengineering in other major metropolitan areas in its 14-state region.

Traditionally, firms have used simulation modeling to analyze manufacturing processes and to evaluate production management strategies. More recently, they have used it to analyze various service processes. U S WEST Communications has used a service process model developed by the operations research group at U S WEST Advanced Technologies, a research arm of U S WEST Communications, to analyze the installation (provisioning) process of a high-capacity fiber-optic telecommunications service. This process is a sequence of tasks that includes interaction with the customer, verification of available facilities, changes to billing information,
and testing equipment. Managers who need to design and improve the process frequently make decisions based on intuition, historical patterns, or descriptive statistics drawn from insurmountable amounts of raw data. We developed a process simulation model to support the managers in designing and reengineering the service process. The model enables managers to gain insight that will help them control the current complex service flow. This insight and an analysis of the process help them to identify areas that need reengineering and to predict the quantitative impact of reengineering efforts.

Business process reengineering, a term coined by Hammer [1990], is the managerial paradigm that many businesses need to radically change the organizational structure of a business process and the policies and methods by which the process operates in order to achieve significant improvements. It is an alternative to "continuous improvement," which aims to incrementally improve existing outdated structures within the process, leaving the fundamental framework of the process intact. Process reengineering, in contrast, emphasizes the overall improvement of a process with respect to its quality, cost, and efficiency. Process simulation modeling allows us to observe the work flows within a service process in their entirety. We can thus easily identify key service functions and subsequently improve, consolidate, or dissolve them through process reengineering.

Since process reengineering emphasizes the overall process rather than the minute details, creating the process model helps us to recognize critical problem areas in the service process. The model helps us to measure the impact of possible changes in the process. Because process reengineering takes effort and money, deciding when and where to carry out drastic changes requires much investigation. As Stewart [1993] emphasizes, core process redesign is costly, usually involves controversial decisions with respect to the work force, and must be applied with discretion. To help it make these critical decisions, the leader’s council of U S WEST Communications asked the operations research modeling group to provide modeling support. The modeling group used simulation modeling to reflect the current status of a service process and to quantify the impact of changes imposed on the process by tracking performance measures. By reflecting the dynamics of a service process, our simulation model has helped managers determine why and where they should reengineer processes. It also helps them to establish tangible management goals. For example, it can help them determine when and how much to increase the work force to maintain or to improve current service cycle times. It can also help them determine how much to spend for improvements to information systems that automate or simplify tasks within the process. As Bae [1993] discussed, simulation modeling provides us with quantitative service performance measures, such as queue length, total cycle time, and idle time at each service center, that help managers allocate their resources.

An Application of Simulation Modeling for U S WEST Communications

DS1 (digital signal level 1) networks are high-capacity, high-speed (1.5Mb/sec) data transfer pathways used primarily by
long distance carriers, large businesses, and government agencies. The DS1 service process (Figure 1) originates with the arrival of a service request from a long distance carrier at the interexchange carrier service center (ICSC) or from a business or government customer at the market unit (MU) service center. ICSC (or MU) confirms the request and issues a service order to a high-capacity provisioning center (HCPC) that generates an engineering specification "work order record details (WORD)." However, if the customer or the service representative at the ICSC or the MU made errors in receiving or issuing the service order, the HCPC issues a "supplement order" and sends it back to the ICSC or the MU for correction. At the HCPC, we have three pathways for the WORD.

First, if the necessary facilities are already in place to handle the request (a pre-provisioned request), we send the WORD directly to the digital services operations center (DSOC) for execution. Second, we may send the WORD to the interoffice facilities current planning center (IFCPC), which orders the materials necessary to fill the request. Third, we may send the WORD to the construction management service (CMS), which is responsible for building new conduits or for attaching new facilities to existing conduits. Once the IFCPC has ordered the materials or CMS has completed, we notify the DSOC to execute the work order to install the service. However, if the DSOC discovers errors made by the HCPC, it sends "re-WORD" to the HCPC for modification. Because this provisioning process includes both forward flows and backward flows, we conceptualized it as a stochastic queuing network model. In the model, we assumed that handling an error takes 50 percent of the time it takes to handle a normal order at each processing center. We also experimented with several sequencing rules, in-

Figure 1: The complex high capacity provisioning process can be conceptualized as a queuing network.
cluding the shortest-processing-time rule, to assign priorities to service requests at each processing center. That is, we assigned the highest priority to preprovisioned requests because their processing time is shortest. We did this to test whether we could reduce overall average cycle time and improve the percentage of customer-requested due date commitments. Below, we discuss five key steps of process simulation modeling in turn.

Our first step in constructing the model was to determine its primary objective and scope. We talked to the managers supervising the process to gather the modeling requirements and agreed that the primary focus of the model should be analyzing the impact of changes in demand, work force, or error rate on the cycle time of connecting a DS1 line, from the service request to the final physical installation. The scope is the Minneapolis/St. Paul region, because Gibson and Welgama [1993], we found that the lack of relevant data prevented us from modeling the true service process. Collecting data was one of the most challenging steps in our project. We initially had difficulty obtaining data in a timely manner because many managers did not consider gathering data important until they were pressured by their supervisors. Also, getting those working in the service centers to agree on common definitions was challenging and time-consuming. For example, we spent a lot of time coming to an agreement on exactly what a “supplement order” is or on the precise meaning of the “processing time” of a task.

In our model, we established several key parameters, such as the distribution of service processing times, the error rate, the scheduling rules, the preprovision rate, and the staffing level at each process center as well as the arrival pattern of service requests. By varying these parameters, we performed various what-if scenario analyses. However, since the complete input data set was either inaccessible or would require an unreasonable amount of resources to collect, we adjusted the scale of the model to accommodate the available data sets. As an example, because arrival data was collected on a daily basis, we were forced to make the time unit of the request arrival pattern daily, though we would have preferred arrival data collected hourly. After collecting suitable data sets, we fit the distribution of daily arrivals with a Weibull distribution and made assumptions about the distribution of task-processing times since the only available data were estimates for the minimum, the maximum, and the mean times based on inter-
views with people working within the centers. We experimented with exponential distributions to represent the distribution of processing times but later found that the Erlang II distribution was a better representation because it had a smaller right tail and less mass distributed at times close to zero.

Building and implementing the simulation model was the third key step. We implemented the conceptual queuing model on the PC with SIMPROCESS, developed by CACI [1992]. We selected this discrete-event simulation programming tool because its animation feature helped us to communicate with the managers. From the beginning, we recognized that good communication was a critical factor. SIMPROCESS is an object-based modeling tool containing preconstructed building blocks that represent work centers, queues, and item generators. These blocks may be attached to represent work flows, and descriptive statistical results may be easily collected. Its animation capabilities let the user observe items moving from work center to work center within the process. It also allows the user to attach queues to blocks to capture work-center delay times. Recently, we have used EXTEND, developed by Imagine That, Inc. [1994] for the Macintosh, which is more flexible than SIMPROCESS and has more graphical capabilities but runs more slowly. We chose EXTEND for the U S WEST project because most of the managers at U S WEST operate Macintosh computers and want to be able to run their own scenarios once we have developed the models.

The fourth key step in implementing our simulation model was to maintain close contact with the managers at the process centers to verify that the model’s intermediate results were valid. This required several visits to interview people working in the centers. Their feedback during the preliminary stages of model development was crucial in verifying that the model accurately represented work flow through the centers.

The fifth and final step was to analyze the model results and present recommendations to managers. Once we had verified that the model output closely reflected previously known estimates of cycle times, we conducted what-if experiments by varying key process parameters. This analysis enabled us to predict the quantitative impact of the process parameters on the cycle time. To do the analysis, we had to develop an appropriate experimental design. We ran the model five to 10 times under each scenario and computed 95 percent confidence intervals for average cycle times, utilization rates, and work-center delay times under steady-state conditions. Finally, we presented the results to the managers and made recommendations for process reengineering.

Results and Recommendations

We ran the models using a set of five what-if scenarios (Table 1) provided by U S WEST process managers. We carried out these five scenarios under three different error rates, five, 20, and 50 percent. We ran the simulation model for a period of six months using daily time intervals, while we observed the total average cycle time as a key performance measure. A primary observation was that a decrease in error rate diminishes the impact of increases in demand and decreases in the

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Force Reduction Rate (%) | Demand Increase Rate (%)
---|---
Case 1 | 10 | 10
Case 2 | 10 | 25
Case 3 | 20 | 5
Case 4 | 20 | 10
Case 5 | 20 | 25

Table 1: We used these five what-if business scenarios in running the models.

work force (Table 2 and Figure 2). Also, we measured the performance of the process centers by tracking their queue lengths and utilization rates. These observations led us to believe that the error rate is a driving force in process improvement. Accordingly, we recommended that process reengineering teams should focus on decreasing error rates and on mechanizing certain manual processes to compensate for the increase in cycle times under various scenarios.

We also conducted experiments to help us understand the impact of key parameters on the cycle time by varying one parameter at a time. These changes included increases in demand, decreases in work force, changes in error rate, and changes in preprovisioning rate. We observed that the cycle time decreases very little for increases in the preprovisioning rate over 60 percent. Also, the cycle time does not increase significantly until the increase in demand is over 20 percent. The current system could withstand an increase in demand of up to 20 percent without the cycle time being affected by more than six percent. Decreases in the work force had a more significant impact on the cycle time than did increases in demand. Even a decrease of only 10 percent resulted in a 12 percent increase in average cycle time. Decreasing the error rate from 50 percent to 30 percent resulted in a reduction in cycle time by 15 percent. The cycle times appeared to be more sensitive to changes in the work force and error rates than to increases in demand.

These results should be interpreted as a managerial guideline, not a managerial decision rule. The simulation model does not reflect qualitative factors that are often major decision-making factors for process reengineering, such as employee morale and organizational culture. The simulation analysis should be considered in concert with these qualitative factors in reengineering a process.

Impact and Future Applications of Simulation Modeling

Our successful modeling helped manag-

<table>
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<th>Error Rate</th>
<th>Force Reduction Rate (%)</th>
<th>Demand Increase Rate (%)</th>
<th>Impact (increase in average cycle time) (%)</th>
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<tr>
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Table 2: Reducing the error rate has a stronger impact on cycle time than does increasing demand and reducing workforce.
ers to determine when and where to reengineer processes. Motivated by this success, U S WEST recently extended process modeling to other regions and to other service-provisioning processes. It is currently using process modeling to investigate the impact of changes in demand, work force, and new process procedures on the cycle time of the provisioning process. In the fall of 1993, U S WEST began merging over 500 old process centers into 26 new centers. These old centers had been created by the three local phone companies that U S WEST absorbed at the time of the Bell system’s divestiture in 1984. The transition to the new centers requires a tremendous amount of planning to relocate people, work, and computer systems while preventing the interruption of service. In addition, the company needs to reengineer the provisioning processes at the new centers to take advantage of the new setting that houses all employees providing a particular service. In the past, those performing the jobs required to deliver services were located in separate buildings, sometimes in separate cites. Locating all employees for a service product in the same office has eliminated errors and inefficient hand-offs. It has also improved communication between employees performing different functions.

The new provisioning process for high-capacity designed services relies on two types of employees: service delivery coordinators and service delivery design imple-
mentors. Coordinators interact with customers to verify that service requests are accurate, to complete the customer billing procedure, and to track the status of requests. The designer implementer has a more technical role. The designer implementer verifies that capacity is available to meet the customer’s requested delivery date, makes necessary software changes, and carries out testing before turning up service.

By using simulation modeling to analyze a particular service-delivery process located in Des Moines before it was completely operational, we predicted that bottlenecks would occur at the job functions performed by the design implementers. We identified these bottlenecks by tracking average queue lengths of the simulated process once it had reached steady state and by tracking utilization ratios (average number of staff busy/number of staff) by job function. Given a fixed staffing ratio, there exists an optimal ratio of service delivery coordinators to designer implementers that eliminates the bottlenecks and balances the work load passing through the process.

Initially the managers did not act on our recommendation because they were not yet comfortable with our predictive modeling. This resulted in lengthy cycle times and complaints from personnel that there were not enough design implementers to do the work promptly. Once the managers realized that the model had accurately predicted the problem, they requested more modeling work for centers opening in Seattle and for other services in Des Moines. They then used the recommended job function ratios in making job offers to prospective employees at the new centers.

Process modeling has business value. Given that businesses have resource constraints, making correct decisions on staffing ratios enables them to maintain high levels of customer service and to reduce the cost of hiring back-up resources to handle bottlenecks. The operations research team continues to help managers of the service delivery processes in opening the new centers. Members of the team are currently investigating the impact of extending and staggering the work hours of the staff at each process center to further reduce cycle time.

According to Lynne Hilderbrand, executive director of designed services for long-distance carrier, business, and government customers at U S WEST,

This modeling has proved valuable to us in Network and Technology Services... It is imperative that this work continue. This modeling effort has a direct impact on our business objectives of cycle time reduction and improvement of customer satisfaction. We have a hunger for more modeling with an emphasis on predictive capabilities. We need these tools for all of our processes. This will help us prioritize activities and resources.

Acknowledgments

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References


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Lynne Hilderbrand, BG S/CXR Designed Services-Carrier, 1005 17th Street, Room 1750, Denver, Colorado 80202, writes,

“The simulation model of high capacity services provisioning has proved valuable to us in Network and Technology Services. I appreciate the work Youngho Lee and Amie Elcan have done to date using Minneapolis as the first application.

“It is imperative that this work continue. We want to populate the model with data from other metropolitan areas and analyze additional what-if scenarios. This will help us prioritize activities and resources for 1994.”