SIMULATION IMPROVES SERVICE AND PROFITABILITY OF AN AUTOMOBILE SERVICE GARAGE

Navin Gupta
Department of Industrial Engineering
2157 Manufacturing Engineering Building
4815 Fourth Street
Wayne State University
Detroit, Michigan 48202 U.S.A.

Edward J. Williams
Management Information Systems & Decision Science
School of Management
University of Michigan – Dearborn
B-14, Fairlane Center South 19000 Hubbard Drive
Dearborn, Michigan 48128 U.S.A.

KEYWORDS

Service operations, process improvement, process management, discrete-event process simulation

ABSTRACT

Simulation has long been an analytical tool of significant importance and power for process improvement. Historically, the earliest and most widespread uses of simulation were in manufacturing industries; however, it was not long before the power of simulation was applied to improve productivity and assess the relative merits of process change alternatives within various service industry segments such as travel, hotel and restaurant, retail stores, and entertainment venues such as theatres and amusement parks. The study described in this paper describes the successful application of simulation to process management and improvement within a business devoted to aftermarket repair of privately owned automobiles and trucks. We describe the problems encountered by the client and how the simulation study illuminated a pathway to significant improvements in customer service and financial profitability.

INTRODUCTION

Discrete-event process simulation originally proved its worth and power as a process improvement tool within the manufacturing sector of the economy (Miller and Pegden 2000). Somewhat more recently, simulation has likewise become highly respected, and its use widespread, in various service industries (Herbst, Junginger, and Kühn 1997). Indeed, a variety of published results attest to the value of simulation within the service sector of the economy. For example, (Pichitlamken et al. 2003) used simulation to analyze a telephone call center handling both inbound and outbound traffic. (Palacis 2000) described the use of simulation to improve the business processing of accounting transactions within supply chains in the timber industry. (Nanthavanij et al. 1996) described an application in which simulation was used to improve services provided by car-park systems.

In this study, the client was the management of a repair and service shop for privately owned vehicles; this shop provides repair and replacement service for exhaust systems, brakes, steering, suspension, and climate-control vehicle systems. The numerous franchised and licensed shops do business in locations as widely dispersed as Brazil, Morocco, New Zealand, and Spain, in addition to locations within the United States, the country of origin of the business nearly half a century ago. Deteriorating economic conditions among consumers, as have prevailed recently within the United States, provoke postponement of new vehicle purchases and hence increase demand for aftermarket repairs of increasingly used vehicles (Nash 2003).

At the particular franchise location in question, management had noticed significant declines in productivity, efficiency, and profitability accompanied by an increase in operational costs, particularly labor costs. Furthermore, increasing service and waiting times, coupled with deterioration of service quality, were eroding consumer goodwill. As examples, more than 12% of total labor time was expended on rework, the number of customers served had just suffered a 23% year-to-year decline, a large work backlog routinely occupied nearly ? of the available floor space, and, due to overtime, total labor cost was increasing markedly. The urgency of these problems impelled the managers to seek counsel and recommendations for improvement.

PROCESS ANALYSIS

Spurred by this urgency, client management and the analysts first identified four performance metrics:

1. Overall productivity = labor hours sold ÷ available hours
2. Labor utilization = actual hours worked ÷ available hours
3. Customer satisfaction, as measured by surveys given all departing customers
4. Overtime = hours required to service all customers – regularly scheduled working hours

All these metrics were strongly and directly related to the problems provoking the study.

Proceedings 16th European Simulation Symposium
György Lipovszki, István Molnár © SCS Press, 2004
ISBN 1-56555-286-5(book) / ISBN 1-84233-106-x(CD)

Next, with extensive help from client management, the analysts constructed a process map. As background, services may be conveniently classified in either of two ways. From the customer's viewpoint, service sought is either periodic preventive maintenance (keep the vehicle in good operating condition) or demand maintenance (restore the vehicle to good operating condition). From the service providers' viewpoint, service is either a minor repair (short duration) or a major repair (long duration). Typically, minor repairs are inspections; major repairs are replacement or restorative work to one or more of the vehicle systems listed previously. The process map comprised seven primary operations:

1. Reception (greet the customer and inquire into the motivation for the customer's visit),
2. Inspection (examine the vehicle to detect all problems meriting attention, possibly extending and/or revising the work deemed necessary at the initial reception),
3. Customer approval (estimating the repair cost and obtaining the customer's approval to undertake the work),
4. Classification of repair (into major or minor; occasionally, both types are required for one vehicle),
5. Performance of repair(s),
6. Final inspection (possibly requiring a short test drive, and certainly requiring cleaning the vehicle of grease or smudge),
7. Invoicing and billing (collecting payment from the customer and returning the vehicle to the customer's custody and use).

Next, the project team (client management and analysts) developed fishbone diagrams (Stevenson 2005) to identify direct causes of the problem. These causes were identified as low productivity and low customer satisfaction, as shown in Figures 1 and 2 below.

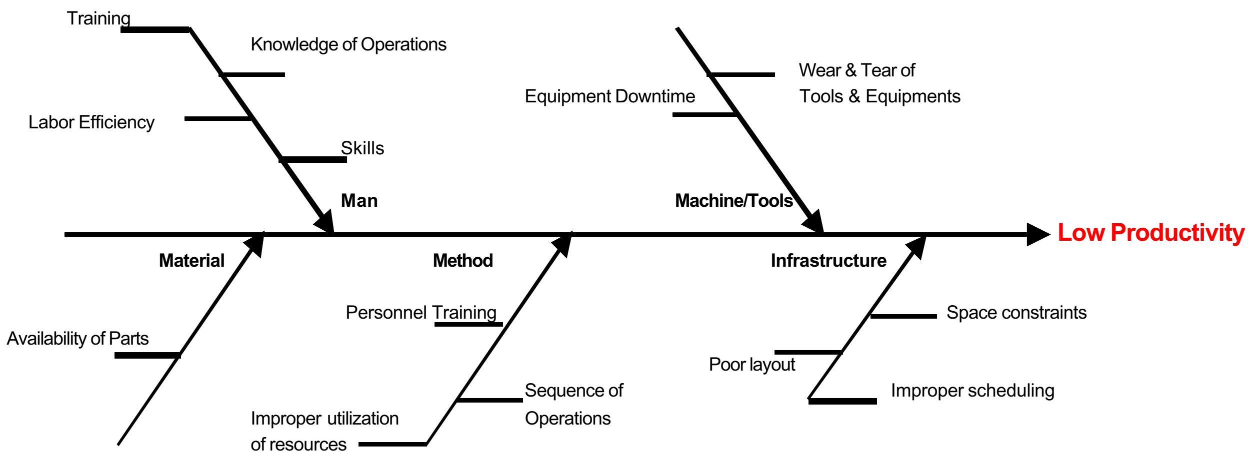

Figure 1. Low Productivity Fishbone Chart

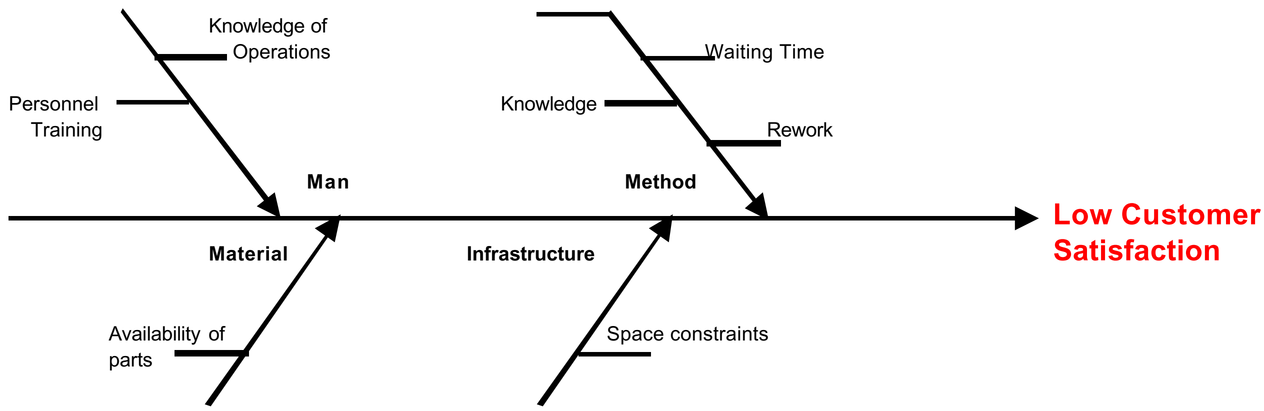

Figure 2. Low Customer Satisfaction Fishbone Chart

After these fishbone diagrams were used to identify these problem causes, preparation of a diagnostic chart (Figure 3, below) helped identify the primary controllable factors. The cause-&-effect mapping was iterated until the primary controllable factors were identified as: inefficient and undisciplined scheduling, inadequate operator training, and sporadic and ineffective equipment maintenance.

DATA COLLECTION

Extensive data collection efforts examined (a) historical data spanning the six months immediately prior to the beginning of the study, (b) direct observational data covering ten complete workdays (two per week for five weeks), and (c) a Customer Satisfaction Survey personally given to and retrieved from every customer during those ten sampled work days. Therefore, the last two phases of data collection entailed 100% sampling. Process times were collected for all seven phases of the process map above. Data were fitted to closed-form distributions whenever appropriate, using the distribution fitter ("Input Analyzer") within the Arena® simulation software (Bapat and Sturrock 2003). The Weibull, triangular, uniform, or normal distributions fitted most observational data sets well, with *p*-values (for rejection of H_0: "Data set plausibly comes from fitted distribution") typically greater than 0.1, and often greater than 0.4. When *p*-values fell below 0.1, the observed data were used directly via an empirical distribution.

THE SIMULATION MODEL AND ANALYSES

The simulation model itself was built using Arena®, a well-known and versatile simulation software package used at both Wayne State University and the University of Michigan – Dearborn for the teaching and practice of discrete-event simulation modeling (Kelton, Sadowski, and Sturrock 2004). This model routinely used standard Arena® modules such as *Create* (customers' vehicles enter the system), *Dispose* (customers' vehicles leave the system), *Process* (vehicles undergo evaluation, repair, or inspection), or *Assignment* (attributes such as type of repair, cost of repair, and duration of repair are assigned to a vehicle). Since the model was built, verified, and validated as a team effort, techniques such as structured walkthroughs (Weinberg 1971), tracing of individual entities, deterministic runs in which all distributions were replaced by their means and results compared with spreadsheet computations, degenerate tests, and extreme condition tests were applied early and often (Sargent 2003). The versions of the model considered the base case (current operations) and four alternatives:

1. Use of an appointment system – customers are expected to make appointments in advance.

   A "Questionnaire Form" was used to evaluate the customers' opinions concerning implementation of an appointment system and also to find the preferred time slot(s) for servicing. Implementing an appointment system would presumably guarantee proper workflow of the overall system, which in turn would ensure proper utilization of resources. Hence an appointment system would be expected to improve productivity, efficiency of labor utilization, and customer satisfaction.

2. Additional training of service personnel.

   With the aim of increasing personnel efficiency, a vigorous personnel-training program could be implemented on a periodic basis. Such an implementation presumably would decrease rework and excessive "work in process". These decreases would then improve utilization of resources, reduce waiting time of the customers, and thereby improve the overall productivity, labor efficiency, and customer satisfaction.

3. Establishment of formal preventive and predictive maintenance procedures.

   In this scenario, the service personnel would be required to follow a daily cleaning schedule of tools and equipment prior to the end of the day. In addition to this expectation, a weekly preventive/ predictive maintenance would be scheduled. Implementation of this alternative presumably would decrease equipment downtime and work in process, in turn leading to better utilization of resources, reduced customer waiting time, and increased efficiency and customer satisfaction.

4. Hiring additional service personnel.

   The number of bays cannot be increased due to space constraints, but in this scenario additional employees would be hired on a permanent basis. From a deterministic spreadsheet model, the investigators identified major repairs as the bottleneck; an additional employee already having the required skills to undertake such repairs could be hired. With the help of the additional worker, the process would presumably flow more smoothly than before, and this alternative should also reduce excessive WIP as well as overburden on employees. It could also be expected to improve customer satisfaction by reducing waiting times.

The first three alternatives represented direct responses to the primary controllable factors previously identified during process analysis. Modeling alternative #1 entailed making the arrival rate of customers nearly constant. For alternative #2, mean cycle times for both major and minor repairs were reduced to 90%-92% of their base case values, and rework was likewise decreased by 8%. For alternative

#3, mean times between failures were increased by 30%, mean times to repair were decreased by 25%, and the preventive/predictive maintenance was scheduled to last ½ hour after every 40 hours of operation. For alternative #4, one additional Arena® *Resource*, representing an employee sufficiently skilled to undertake both major and minor repairs, was added to the bottleneck process, i.e., Major Repair.

The assumptions that alternative #2 (training) would reduce repair times to 90%-92% of their baseline values, and that rework would decline by 8%, was acknowledged as uncertain by both client management and the simulation analysts. These assumptions emerged from the client's estimates, and those estimates in turn emerged from discreet observations of both fraternal and competitive franchises in the aftermarket vehicle repair business. Certainly it is widely recognized that predictions of training effectiveness are difficult to make and inherently uncertain (Wickens, Gordon, and Liu 1998). Likewise, the predictions that devoting 1¼% (½ hour of every 80 hours) of potential work time to preventive maintenance would extend mean times to failure by 30% and decrease repair times by 25% were hazy. These estimates also emerged from client estimates, and additionally corresponded reasonably well with case studies cited by (Leemis 1995) extolling the values of preventive maintenance. The second author vividly remembers hearing a wise supervisor and mentor remark years ago (Crabb 1975), "It's amazing what preventive maintenance will prevent." Due to the uncertainly surrounding these estimates, all of them were examined in detail via sensitivity analyses, both for verification and validation and to assess the degree to which model results depended on the accuracy of these assumptions (Balci 1998).

The various alternatives called for changes in the ongoing process, organizational structure, infrastructure and technology used in the organization. The anticipated changes with respect to various alternatives are shown in Table 1:

Alternatives	Process	Organizational	Technology / Infrastructure
AS-IS	No Change	No Change	No Change
Appointment System	No Change	An additional responsibility of making all appointments as well as maintaining documents, keeping track of Appointments.	There will be an additional requirement of some kind of scheduling software, which will help in implementing Appointment System.
Training of the Service Personnel	Vigorous Personnel Training program is implemented on a periodic basis.	The Management is required to arrange a Training Program for the service personnel as well hire certain instructor who trains the employees.	Training Manuals/documentations/ visual aids are to be generated to aid in training program.
Preventive & Predictive Maintenance	The Service Personnel are required to follow a daily cleaning schedule of tools and equipments prior to the end of the day. In addition to this a weekly preventive / Predictive Maintenance is Scheduled.	Responsibility is to be given to the Service Personnel to clean the tools & equipments prior to the end of the day.	The Service Station has to invest in the purchase of necessary Tools to perform Preventive / Predictive Maintenance.
Hire Additional Service Personnel	No Change	An additional labor cost is incurred, and also the organization should ensure that the new hired employees are skilled.	No Change

Table 1. Anticipated Process, Organizational, and Technology Changes under Various Scenarios

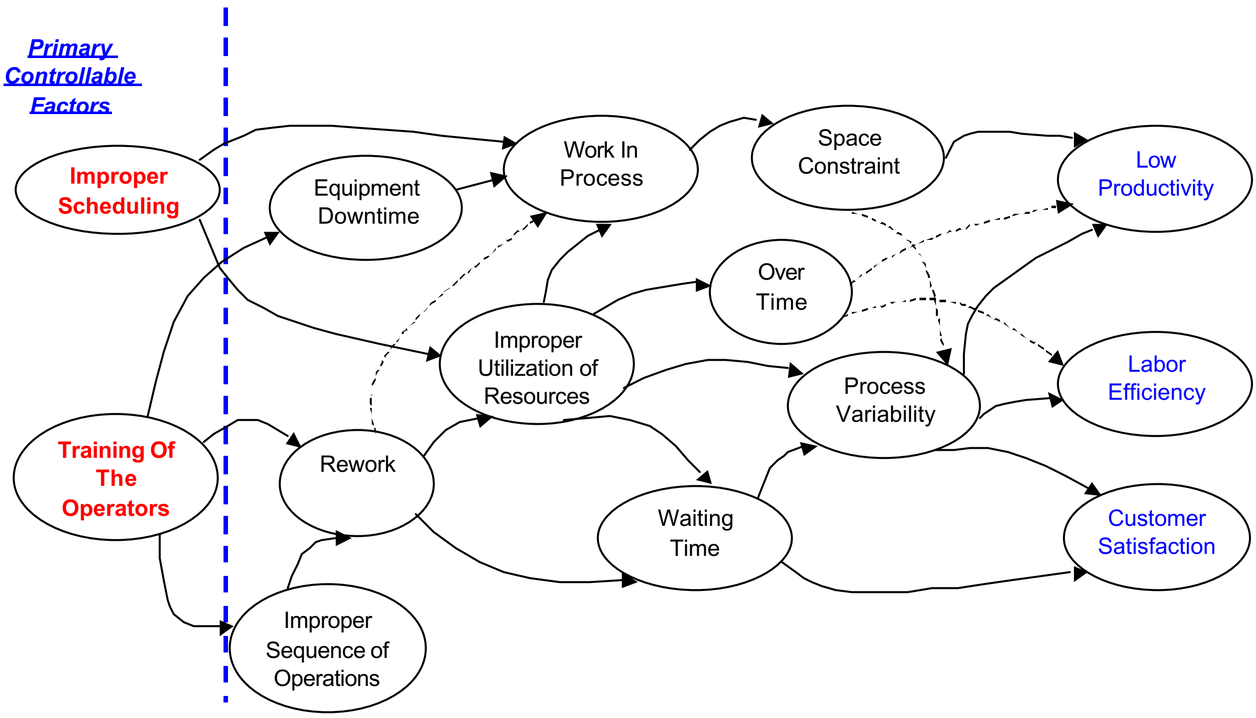

Figure 3. Diagnostic Chart

RESULTS AND CONCLUSIONS

Since the repair shop runs five eight-hour days per week plus necessary overtime to complete that day's incoming work, it was modeled as a terminating system. All alternatives were run for ten replications, and each replication comprised ten eight-hour days (two calendar weeks), thereby permitting the routine construction of confidence intervals using the Student-*t* distribution inasmuch as results from these replications were pairwise independent.

Mean performance metrics for the base case and the five alternatives were:

Model	Product-ivity	Overtime (hours/week)	Labor Utilization
Base case	1.38	15.4	0.39
Appointments	1.61	16.6	0.37
Training	2.10	7.8	0.38
Maintenance	1.85	13.1	0.39
New Service Personnel	2.09	11.0	0.45

Table 2. Average Results for Five Scenarios

Various graphs (Figures 4, 5, and 6 below) were plotted to assist client engineers and managers in comparing the different alternatives against the performance metrics of productivity, overtime, and labor utilization.

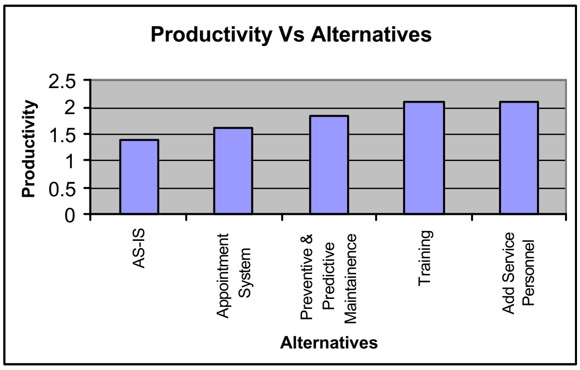

Figure 4. Predicted Productivity Under Various Alternatives

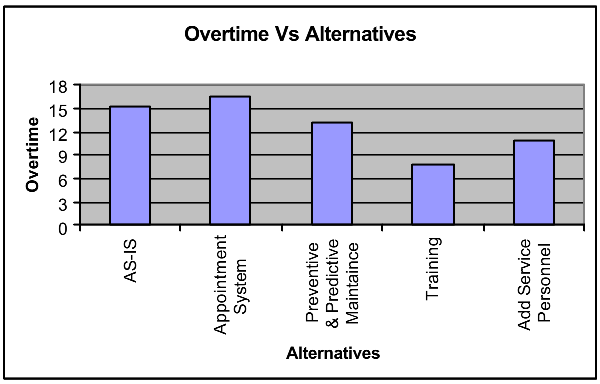

Figure 5. Predicted Overtime Under Va rious Alternatives

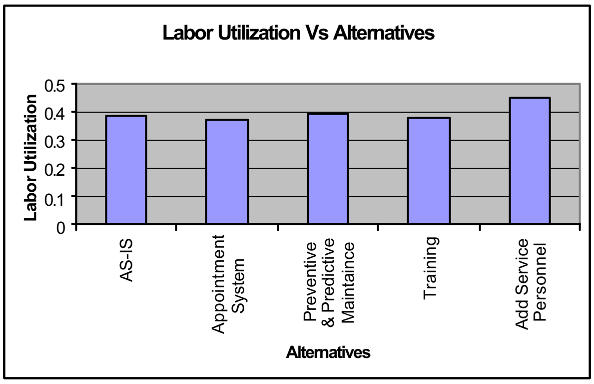

Figure 6. Labor Utilization Under Various Alternatives

It is particularly notable that adding an employee (alternative #4) increased labor utilization; typically, exactly the opposite would be expected. The franchise managers were intrigued to learn from the model that the bottleneck (major repairs) would be sufficiently ameliorated by addition of one worker to increase the utilization of many other workers by reducing their time spent waiting for tasks to arrive, and hence improving overall workload balancing.

Attractive as this improvement in utilization appeared, the client management was even more enticed by the promise of alternative #2 (training), which the analyses predicted would increase productivity as much as adding a new employee, achieve a marked reduction in overtime, and maintain overall labor utilization. The overtime reduction was important to both management (containment of costs) and the workers (greater predictability of their work schedules and hence freedom to schedule activities within their personal and family lives). Both managers and workers realized that the reduced overall amount of overtime could more readily be assigned to those workers more eager to work it – workers' attitudes toward overtime, as is typical in a diverse workforce, varied across the entire spectrum from alacrity to revulsion. From an economic viewpoint, training (as compared to addition of a worker) would increase, rather than decrease, the franchise's ability to adopt to inevitable fluctuations in amounts and types of repair services demanded by the marketplace. Furthermore, almost all workers viewed the training as an enhancement of their long-term employability and as evidence of the willingness of management to invest in them.

Thorough analysis of the criteria must precede making a decision; making the decision then requires consideration of various economic and stochastic scenarios. Cost Benefit Analysis gives us the best economically sound alternative, whereas Sensitivity analysis is used to check the *robustness* of the best alternative.

The factors considered for Cost Benefit Analysis were:

1. Overall Productivity
2. Labor Efficiency
3. Overtime
4. Total Cost

On the basis of Cost Benefit Analysis, it was found that Alternative 2 (Training of Service Personnel) was the best alternative.

Sensitivity analysis of the alternatives was done by increasing & decreasing the values of the factors considered for Cost Benefit Analysis. On the basis of Sensitivity Analysis, it was found that Alternative 2 (Training of Service Personnel) was also the most *robust* alternative.

Therefore, management selected the training alternative for immediate implementation. Data on the four performance metrics were collected again for a six-month period, beginning three months after the training ended (to allow it to achieve full effect). These metrics showed improvements consistent, to within 6%, of those predicted by the simulation analyses of alternative #3. Furthermore, both semi-formal surveys of employee morale and informal observations of it (e.g., noting a reduction in employee turnover) showed improvement, and management felt justified in attributing at least a portion of this improvement to the increased security the employees felt in their careers and the decreased frequency with which unwilling employees had to be dragooned into working unwanted overtime.

In conclusion, we remark that the thorough process analysis and mapping completed before construction of the simulation model, and used to identify alternatives worthy of modeling and analysis, closely match the recommendations of (Eldabi, Lee, and Paul 2003) relative to business process simulation. Certainly nothing inherent in the training alternative precludes the additional alternatives of increasing preventive maintenance and/or hiring an additional worker; therefore, the client's involvement with simulation has extended itself into further investigation of these strategies.

ACKNOWLEDGMENTS

The first author gratefully acknowledges the mentorship and guidance of Professor Olugbenga Mejabi of Wayne State University and the project assistance of colleagues Saravanan Selveraj, Mayo Santosh, and Asad Sami. The second author likewise gratefully acknowledges the mentorship of Professors Onur M. Ülgen and Benjamin Lev of the University of Michigan – Dearborn. Both authors are pleased to acknowledge the helpful criticism of an anonymous referee, and the assistance of colleague Neelesh Kale in preparing the final manuscript.

REFERENCES

Balci, Osman. 1998. "Verification, Validation, and Testing." In *Handbook of Simulation*, ed. Jerry Banks, 335-393. New York, New York: John Wiley & Sons, Incorporated.

Bapat, Vivek, and David T. Sturrock. 2003. "The Arena Product Family: Enterprise Modeling Solutions." In *Proceedings of the 2003 Winter Simulation Conference*, Volume 1, eds. Stephen E. Chick, Paul J. Sánchez, David Ferrin, and Douglas J. Morrice, 210-217.

Crabb, Howard C. 1975. Personal oral communication with Edward J. Williams.

Eldabi, Tillal, Man Wai Lee, and Ray J. Paul. 2003. "A Framework for Business Process Simulation: The Grab and Glue Approach." In *Proceedings of the 15th European Simulation Symposium*, eds. Alexander Verbraeck and Vlatka Hlupic, 291-296.

Herbst, J., S. Junginger, and H. Kühn. 1997. "Simulation in Financial Services with the Business Process Management System ADONIS." In *Proceedings of the 9th European Simulation Symposium*, eds. Winfried Hahn and Axel Lehmann, 491-495.

Kelton, W. David, Randall P. Sadowski, and David T. Sturrock. 2004. *Simulation with Arena*, 3rd edition. Boston, Massachusetts: The McGraw-Hill Companies, Incorporated.

Leemis, Lawrence M. 1995. *Reliability: Probabilistic Models and Statistical Methods*. Englewood Cliffs, New Jersey: Prentice-Hall, Incorporated.

Miller, Scott, and Dennis Pegden. 2000. "Introduction to Manufacturing Simulation." In *Proceedings of the 2000 Winter Simulation Conference*, Volume 1, eds. Jeffrey A. Joines, Russell R. Barton, Keebom Kang, and Paul A. Fishwick, 63-66.

Nanthavanij, S., P. Yenradee, V. Ammarapala, and S. Wongtiraporn. 1996. "Performance Analysis of Car Park Systems Using Simulation." In *Proceedings of the 1st Annual International Conference on Industrial Engineering Applicatioons and Practice*, eds. Jacob Jen-Gwo Chen and Anil Mital, 726-731.

Nash, Tom. 2003. "Increased Used-Vehicle Sales Spur Aftermarket Repairs." *Motor* 200(3):58.

Palacis, Edgars. 2000. "Timber Accounting and Logistics System." In *Proceedings of the Second International Conference Simulation, Gaming, Training and Business Process Reengineering in Operations*, eds. Yuri Merkuryev, Birger Rapp, and Galina Merkuryeva, 231-234.

Pichitlamken, Juta, Alexandre Deslauriers, Pierre L'Ecuyer, and Athanassios N. Avramidis. 2003. "Modelling and Simulation of a Telephone Call Center." In *Proceedings of the 2003 Winter Simulation Conference*, Volume 2, eds. Stephen E. Chick, Paul J. Sánchez, David Ferrin, and Douglas J. Morrice, 1805-1812.

Sargent, Robert G. 2003. "Verification and Validation of Simulation Models." In *Proceedings of the 2003 Winter Simulation Conference*, Volume 1, eds. Stephen E. Chick, Paul J. Sánchez, David Ferrin, and Douglas J. Morrice, 37-48.

Stevenson, William J. 2005. *Operations Management*, 8th edition. Boston, Massachusetts: The McGraw-Hill Companies, Incorporated.

Weinberg, Gerald M. 1971. *The Psychology of Computer Programming*. New York, New York: Van Nostrand Reinhold Company.

Wickens, Christopher D., Sallie E. Gordon, and Yili Liu. 1998. *An Introduction to Human Factors Engineering*. New York, New York: Addison Wesley Longman, Incorporated.

AUTHOR BIOGRAPHIES

NAVIN GUPTA received his master's degree in Industrial Engineering at Wayne State University, Detroit, MI in December 2003. He has been deeply involved with the area of Industrial and Quality Engineering. His career in industry began after receipt of his bachelor's degree in Industrial Engineering from Regional Engineering College, India. His first assignment was as an Industrial Engineer at Central Institute of Hand Tools followed by Quality Control Engineer at Sondhi Industries. He is a Certified Quality Engineer and also a member of the American Society of Quality (ASQ). He has been involved in the area of Computer Simulation for the past two years. He did his research in simulation in his master's program; the research was related to an articulation of strategic budgeting with Monte Carlo simulation analysis. His e-mail address is navin@wayne.edu.

EDWARD J. WILLIAMS holds bachelor's and master's degrees in mathematics (Michigan State University, 1967; University of Wisconsin, 1968). From 1969 to 1971, he did statistical programming and analysis of biomedical data at Walter Reed Army Hospital, Washington, D.C. He joined Ford Motor Company in 1972, where he worked until retirement in December 2001 as a computer software analyst supporting statistical and simulation software. After retirement from Ford, he joined Production Modeling Corporation, Dearborn, Michigan, as a senior simulation analyst. Also, since 1980, he has taught classes at the University of Michigan, including both undergraduate and graduate simulation classes using GPSS/H™, SLAM II™, SIMAN™, ProModel®, SIMUL8®, or Arena®. He is a member of the Institute of Industrial Engineers [IIE], the Society for Computer Simulation International [SCS], and the Michigan Simulation Users' Group [MSUG]. He serves on the editorial board of the *International Journal of Industrial Engineering – Applications and Practice*. During the last several years, he has given invited plenary addresses on simulation and statistics at conferences in Monterrey, México; Istanbul, Turkey; Genova, Italy; and Riga, Latvia. He served as program chair for the 2004 Summer Computer Simulation Conference in San José, California, U.S.A.; and will do likewise for the 2005 Summer Conference in Philadelphia, Pennsylvania, U.S.A. His e-mail address is: williame@umdsun2.umd.umich.edu and his university Web-page can be found at http://www-personal.umd.umich.edu/~williame.