SIMULATION SUPPORTS IMPROVEMENT AND EXPANSION OF AUTO DETAILING SERVICE

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ABSTRACT

When, some decades ago now, discrete-event process simulation first expanded from academic research into the commercial arena, its first and very enthusiastic users were manufacturing enterprises. From there, simulation has deservedly expanded into other realms: Health care, warehousing, supply chain and transshipment improvement, public transport (improvements to airports, highway networks, and railroad operations), and service industries.

We provide here an example of simulation applied to a service industry – the detailing of privately owned vehicles. Such detailing, properly and thoroughly done, can make a vehicle "like new" – shining headlights, restored upholstery, "squeaky clean" inside and out, and all surfaces vigorously polished. In the simulation analysis examined in this paper, a recently established (2021) auto detailing service in the United Arab Emirates, experienced significant increase in customer demand. The entrepreneur, having established an excellent reputation for service quality, sought the most cost-effective ways to accommodate the increased demand with no degradation of (indeed, even improvement to) its service: Short waiting times and "delivery when promised."

INTRODUCTION

Decades ago now, when discrete-event process simulation first vigorously expanded from academia to business usage, the first and very enthusiastic users of simulation were manufacturing companies; they soon achieved reduced inventory costs, greater reliability of delivery, lower operational costs, and increased bottom-line profits by applying the recommendations of simulation analyses. Subsequently, simulation usage has expanded to, and achieved similar benefits in, health care operations such as clinics, hospitals, and emergency departments, as exemplified by (Comas, Cleophon, and Büsing 2021); warehousing operations; supply chain and transshipment enterprises (for example, (Compagno, De Filippo, and Marchese 1997) improves a collection system for fresh oranges); transportation networks such as railroads, airports, and highway systems (for example, (Diaz, Vásquez, and Wainer 2001) discusses vehicle routing in heavy urban traffic); and service industries such as retail stores and service enterprises. Further illustrating the broad applicability of discrete-event process simulation beyond manufacturing, (Farahmand and Martinez 1996) applies simulation to detailed analysis of a fast-food restaurant, whereas (Legato, Malizia, and Mazza 2016) uses simulation to measure and improve the purchasing process in a public university, and (Fani et al 2022) successfully applied simulation to the design of business processes associated with the rental of fashionable accouterments of attire (e.g., clothes, shoes, handbags).

In this paper, we document the use of simulation analysis to improve the operation and customer service metrics of a vehicle-detailing shop. The remainder of this paper is organized as follows: The next section presents an overview of the operation of the vehicle-detailing operation from the viewpoints of both managers and customers. Next, we describe the data required by the model and indicate how those data were obtained, or estimated when necessary. Next, we document the processes of building, verifying, and validating the simulation model. Subsequently, we describe the results provided by the model and our analysis of them, leading to recommendations provided to the business entrepreneur. Then we summarize the achievements of this project and describe the directions future work might well undertake.

OVERVIEW OF DETAILING SERVICES AND OPERATIONS

The client company in the simulation study is an auto-detailing business based in the United Arab Emirates and founded by a single entrepreneur, less than one year old at the time of the study and rapidly gaining customers. This business niche is one of many revolving around aftermarket products and services for automobiles (Horowitz and Shilling 1989). Furthermore, it can well

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be, metaphorically, a fruitful acorn from which an oak of profitable business grows (Eberbach 2022). The company provides a full slate of auto-detailing services to restore "showroom shine": Washing and polishing the vehicle both inside and out (e.g., no trace left of pet hair or food crumbs between the seats or under the floor mats), restoring the original transparency of windshield [windscreen], rear window, and side windows which have gradually acquired a film reducing vision, polishing the lenses of the headlamps and taillamps, which likewise have gradually acquired a film reducing their brightness and clarity, restoring all leather surfaces to their original cleanliness and suppleness, applying a ceramic coating to the vehicle exterior to enhance its appearance and form a highly protective coating, and thus making the vehicle "newer than new" – in the words of the proprietor, "I want the customer to be excited to drive the vehicle away." Indeed, from the viewpoint of some customers (those planning a private sale of their vehicle), the cost of this service is less than the increase in price the vehicle can command in such a sale.

This business is open six days a week, Monday-Saturday inclusive, from nine AM to seven PM. There are two workers in addition to the proprietor. A lunch break is scheduled for them from two PM to four PM; one employee takes lunch from two PM to three PM, and the other takes lunch between three PM and four PM.

The seemingly inconspicuous and humble, yet vital, constraint facing the entrepreneur is the supply of cleaning cloths available to the employees throughout the day. "Equipment full of dirt can't clean!" Every cloth applied to a customer's vehicle must be freshly washed – immaculately clean – when used. A batch of these cloths contains, by definition, 25 cloths. The business uses one batch on most days; two batches on a busy day (and these "busy days" are becoming more frequent). A third "backup" batch of cloths, as a matter of policy, is available on a contingency basis. Current policy is that one employee devotes 55 minutes, at the end of each business day (i.e., from 7PM when the door closes to new customers, to 8PM), to hand-launder the cloths used that day. During the same "post-closing" hour, the other employee does general cleaning; e.g., mopping the floors, clearing litter left by customers (annoyingly, an incoming customer frequently "dumps" the vehicle's ashtray), and putting equipment away ("a place for everything and everything in its place," one of the 5S mottoes (Hogrefe 2013)). The client asked the simulation team to address the question "Would it be economically advantageous to contract to have the cloths machine-washed daily?" The client already had the economic information that machine-washing the cloths would require five minutes and free the employee who now hand-washes them for other tasks. However, machine washing reduces the useful lifetime of a cloth by half – and, as the client remarked in passing, "Might there be a problem if we wait for clean cloths until the scheduled next delivery from the laundry?"

DATA COLLECTION AND ANALYSIS

The members of the simulation analysis team collected data via a detailed questionnaire presented to the business proprietor, who promptly provided the data to the best of his knowledge. These data were then reviewed and discussed by all team members. The questionnaire and the data collection process took about one week and involved multiple chats and telephone calls with the owner to discuss the details of the data provided. The concern relative to washing the cloths was also discussed to get more information so it can be used in the analysis. Table 1 in the Appendix summarizes the average monthly customers and average service time reported by the client and subsequently used as a baseline to understand the overall customer volume to aim for with our simulation.

Employees will routinely preempt long services (polishing and coating) to accommodate a customer wanting only a car wash. A customer originally requesting the polishing service will "upsell" to inclusion of an interior detailing with probability 0.3, and will "upsell" to the ceramic coating service with probability 0.5.

MODEL DEVELOPMENT, VERIFICATION, AND VALIDATION

Subsequent to discussion and comparative evaluation of various analytical tools and software packages available for discrete-event simulation and concomitant analyses, the client and the team of analysts decided jointly to use the well-regarded and vigorously supported Simio® software package to build the simulation model (Prochaska and Thiesing 2017) and (Smith and Kelton 2021). This software provided standard constructs such as Servers (at which work is done), Workers (who are needed for labor; various Servers may compete for their attention), scheduling capability (used to model arrival of customers only during open-for-business time, and to model the workers' lunch breaks), and convenience of constructing a rudimentary but communicative animation concurrently with constructing the model). The preemption present in the system, as described above, is typically more difficult to model than priority in queues; however, Simio® provides ability to conveniently specify the steps an entity (here, a customer requesting only a car wash) takes after successfully preempting another entity (here, a customer requesting car polishing or ceramic coating) – and the steps the "victim" (preempted) entity takes (e.g., undergoing an increase in priority making it much less likely to be preempted a second time). Using this software, it was routine, for example, to specify that a vehicle undergoing ceramic coating must remain in the system an additional day for curing time, but requires no employee attention during that additional time. The Stat::Fit® software, which accompanies Simio®, enabled analysis of input data sets to determine that, for example, triangular distributions with specific parameters suitably represent the time required to clean the cloths, whether manually or automatically. This software likewise supported the use of exponential distributions to characterize customer interarrival times (Leemis 2002) and (Benneyan 1998). Likewise, using Bernoulli distributions, it was routine to specify that certain percentages of customers are successfully "upsold" an interior-detailing or a ceramic-coating service. Simio® also provides, at very little incremental effort, an informative animation; a screenshot of this animation is shown as Figure 1, Appendix.

After completing model development, the analysts examined the functionality and results of the simulation to verify and validate the model (Sargent 2011). Verification entailed, for example, ensuring that all entities were flowing through the system properly – beginning with a trial run in which only one entity entered the model, and was then tracked step-by-step to its exit. Verification also included structured walkthroughs within the team of analysts; each team member explained the portion of the model he or she constructed to the other team members, and invited comment on any errors noticed or improvements needed (Weinberg 1971). At a broad level, this meant confirming that entities are created at the CustomerSource, travel along the path to the services area, and an employee is seized to work on the car in the service area. Once service is finished, entities properly traveled along the path to the CustomerSink and the entity is destroyed. The path was specified to take one minute in duration, as the client confirmed this process to load them in and move them out was fairly quick. The analysis likewise confirmed that all five types of entities get created throughout the run to ensure each type of customer is accounted for.

In addition, the analysts confirmed that no entities arrive outside of the shop's standard working hours of 9AM - 7PM. Once the shop closes at 7PM, the work shifts over to cloth cleaning, where one worker is seized and works to clean cloths for approximately 55 minutes until the ClothCleaning server shuts off at 8PM. Lastly, the shop opens up again at 9AM the following day with both workers providing service together. These were the primary steps necessary for verification, and once they were completed and mistakes routinely corrected, the analysts were confident the model was working as intended.

To validate our model, we then ensured that the system closely matched the data provided to us by the client and was therefore an accurate representation of the business. First, we fine-tuned the total volume and mix of customer types created by the model by employing an appropriate service mix property in our Customer Data table, in accordance with the second column of Table 1 (Appendix). Then, experiments which varied customer interarrival time were run to judge which parameters would best coincide with data provided to us by the client.

EXPERIMENTATION AND RESULTS

For experimentation and output analysis (Nakayama 2003), the model was run as a steady-state (not terminating, as might be expected, e.g. the retail store analyzed in (Pethers et al. 2021)) system, because almost every day's work includes some customers' cars remaining overnight for continuation of work. Simio® provides convenient numerical and graphical summaries of output across scenarios, as shown in Figures 2 and 3 in the Appendix. Importantly, criteria which can be changed among scenarios area not only numbers (e.g., the size of a work crew), but other criteria such as which work schedule to follow, or which vehicle routing discipline to obey. The analyst then specifies KPIs (key performance indictors) to be output and compared among the scenarios examined.

It might naturally be expected that this simulation be considered that of a terminating system, as is common when analyzing customer-service businesses which open and close their doors at set times daily. However, and with customer acquiescence, vehicles needing "the full gamut of services" are often left overnight. Therefore, the warm-up time was set to one day, and the model run time to 25 (business) days, thus conveniently approximating one calendar month. Then, eight scenarios were defined, as shown in Table 2 in the Appendix, and run for 20 replications each:

At this point, the simulation analysis provided valuable warnings. First, the system is already sensitive to more frequent arrivals; if the average interarrival time falls much below two hours, customer average waiting time will more than double. The client was grateful for this warning, since the more frequent arrivals had not yet been observed, but were anticipated partly due to a planned increase in advertising expense and partly due to gradually increasing population of the local geographic area. These results emphatically stressed to the client that system performance and customer satisfaction depend very strongly on the interarrival time *when interarrival times are assumed exponential* (as the distribution-fitting software had confirmed is currently the case). A wait time of four hours, as determined by casual conversations with customers, is a "tipping point" – more than half a working day. Customers often remarked "If I drop the car off in the morning, I want to pick it up on my lunch hour" or "If I drop the car off on my lunch hour, I want to pick it up on my way home from work." Furthermore, these results warned that contracting the cleaning of the cloths out, and thereby becoming dependent on their redelivery after laundering, although not a point of risk currently, would introduce a severe risk (Scenario 8) under the hypothesis of customers arriving more frequently in the future. Therefore, in the short term, the client undertook two business decisions: (a) renouncing the initially financially attractive alternative of subcontracting the laundering of the cleaning cloths, and (b) forgoing almost all advertising expense until a fundamental process redesign .

CONCLUSIONS AND FUTURE WORK

The client is eager to expand the business further, but physical expansion (entailing more land and garage space) is a long way off. Two of the analysts made insightful remarks during the simulation project: (a) there is a conspicuous slack time beginning just after noon and extending during much of the afternoon, and (b) the sensitivity of the system performance metrics to average interarrival time is largely a consequence of the high variability of the exponential interarrival times. Therefore, the client plans to alter his business strategy by inviting (likely with price and/or timeliness incentives) the making of reservations for the longer-duration services. An even more recent simulation analysis (Koyanagi 2023) has documented the high ability of reservation-taking to improve overall service at a cellular-telephone retail store. The team of analysts is standing by to compare and contrast the relative merits of various reservations strategies under consideration.

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REFERENCES

Benneyan, James C. 1998. Distribution Fitting Software Makes Simulation More Attractive, Viable in Many Applications. *OR/MS Today* (98:38,1-10).

Comas, Martin, Catherine Cleophas, and Christina Büsing. 2021. Patients, primary care, and policy: Agent-based simulation modeling for health care decision support. In *Health Care Management Science* 24(4):799-826.

Compagno, Lucio, Danilo De Filippo, and Domenico Marchese. 1997. Optimization of a Collection System by Simulation Logistics Improvements. In *Proceedings of the 9th European Simulation Symposium*, eds. Winfried Hahn and Axel Lehmann, 466-469.

Diaz, Andrea, Verónica Vázquez, and Gabriel Wainer. 2001. Vehicle Routine in Cell-DEVS Models of Urban Traffic. In *Proceedings of the 13th European Simulation Symposium*, eds. Norbert Giambiasi and Claudia Frydman, 657-661.

Eberbach, Jennifer. 2022. Brighton Teen Entrepreneur Launches his own Auto Detailing Service while Still in High School. In *Livingston Daily*, 27 June 2022.

Fani, V., F. Pirola, G.. Pezzotta, R. Bandinelli, and B. Bindi. 2022. Design Product Service Systems by Using Hybrid Simulation: A Case Study in the Fashion Industry. *Sustainability (Switzerland)* 14,9), article #5207.

Farahmand, Kambiz and Alejandro Francisco Garza Martinez. 1996. Simulation and Animation of the Operation of a Fast Food Restaurant. In *Proceedings of the 1996 Winter Simulation Conference*, eds. John M. Charnes, Douglas J. Morrice, Daniel T. Brunner, and James J. Swain, 1264-1271.

Hogrefe, Kristen. 2013. 5S: Sort, Set in Order, Shine, Standardize & Sustain. In *Industrial Safety & Hygiene News*, 7 June 2013.

Horowitz, D. and Shilling, D. 1989. *The Business of Business*. Harper & Row, Publishers, New York, New York.

Koyanagi, Junji. 2023. A Staff Scheduling Problem of Customers with Reservations in Consideration with Expected Wait Time of a Customer without Reservation. In *Applications in Reliability and Statistical Computing*, ed. Hoang Pham, 219-226. Cham, Switzerland: Springer International Publishing Aktiengesellschaft.

Leemis, L. 2002. Stat::Fit Fitting Continuous and Discrete Distributions to Data. *ORMS Today* 29 (3), 52-55.

Legato, Pasquale, Lidia Malizia, and Mazza. 2016. Simulation-Based Performance Measurement: Assessing the Purchasing Process in a Public University. In *Proceedings of the 30th European Conference on Modelling and Simulation*, eds. Thorsten Claus, Frank Herrmann, Michael Manitz, and Oliver Rose, 33-40.

Nakayama, M., 2003. Analysis of Simulation Output. *Proceedings of the 2003 Winter Simulation Conference, Volume 1*, 49-58. December 7-10, New Orleans, Louisiana (United States of America).

Pethers, Caitlin, Marie Ruesga, Parker Moesta, and Edward J. Williams. 2021. Simulation Improves Service and Operations at a Franchise Retail Store. In *Proceedings of the International Conference on Industrial Engineering and Operations Management*, Monterrey, México, 3-5 November 2021.

Prochaska, K. and Thiesing, R. 2017. Introduction to Simio. *Proceedings of the 2017 Winter Simulation Conference*, 4410-4419. December 3-6, Las Vegas, Nevada (United States of America).

Sargent, Robert G. 2011. Verification and Validation of Simulation Models. In *Proceedings of the 2011 Winter Simulation Conference*, eds. S. Jain, R. R. Creasey, J. Himmelspach, K. P. White, and M. Fu, 183-198.

Smith, J., Sturrock, D., and Kelton, W. 2021. *Simio and Simulation: Modeling, Analysis, Applications*. 6th ed. Sewickley, Pennsylvania (United States of America): Simio LLC.

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

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EDWARD J. WILLIAMS holds a master's degree in mathematics (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 PMC, 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. He is a member of the Institute of Industrial and Systems Engineers [IISE], the Society for Computer Simulation International [SCS], and the Michigan Simulation Users Group [MSUG]. During the last several years, he has given invited plenary addresses on simulation and statistics at conferences in Monterrey, México; İstanbul, Turkey; Genova, Italy; Rīga, Latvia; and Jyväskylä, Finland. He served as a co-editor of *Proceedings of the International Workshop on Harbour, Maritime and Multimodal Logistics Modelling & Simulation* (2003), a conference held in Rīga, Latvia. Likewise, he served the Summer Computer Simulation Conferences of 2004, 2005, and 2006 as Proceedings co-editor. He was the Simulation Applications track coordinator for the 2011 Winter Simulation Conference. A paper he co-authored with three of his simulation students won "best paper in track" award at the Fifth International Conference on Industrial Engineering and Operations Management, held in Dubai, United Arab Emirates, in March 2015.

APPENDIX

Figure 1. Animation of the Basic Model

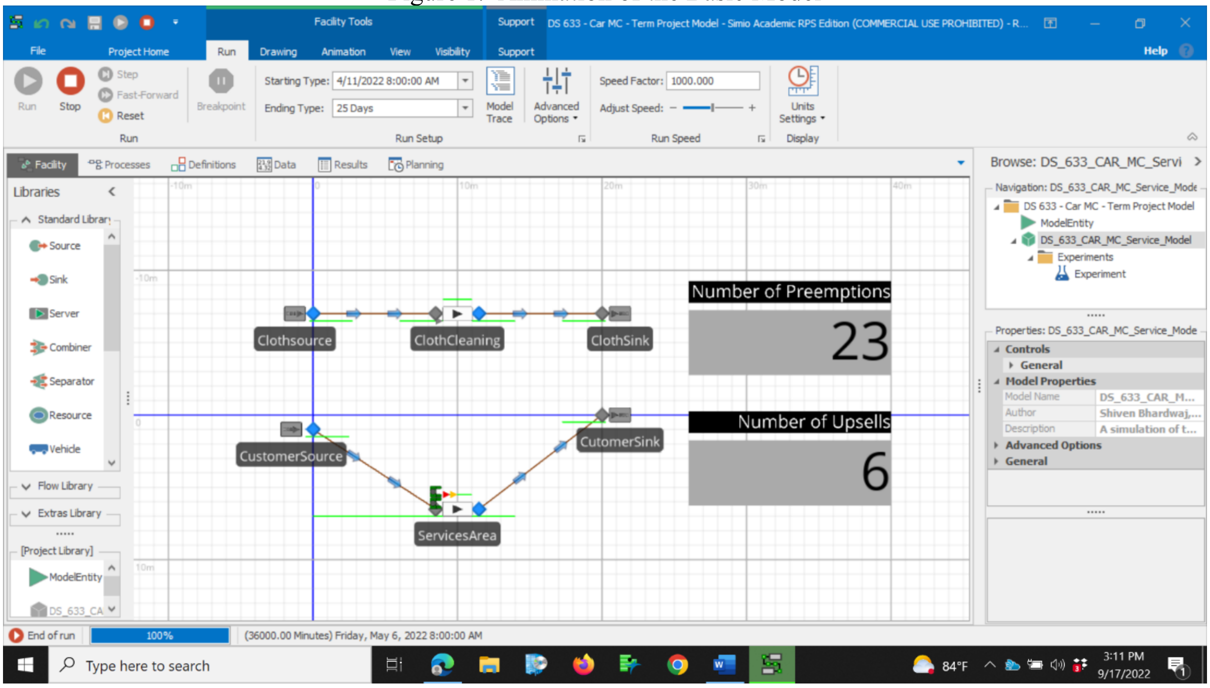

Figure 2. Numerical Summary of Results of Experimental Scenarios

Scenario			Controls		Responses			
Name	Status	Completed	ClothCleaning_ProcessingTime (Minutes)	CustomerSource_InterarrivalTime (Hours)	ServiceUlt	EmplyUlti	AveWaitTime ...	AveNumWait
IntArrTime_2.5	Completed	20 of 20	Random.Triangular(52,55,58)	Random.Exponential(2.5)	58.4468	58.0234	3.28582	0.837719
IntArrTime_2.75	Completed	20 of 20	Random.Triangular(52,55,58)	Random.Exponential(2.75)	54.0173	54.3632	2.39811	0.56067
IntArrTime_3	Completed	20 of 20	Random.Triangular(52,55,58)	Random.Exponential(3)	44.3213	46.426	1.71501	0.323571
IntArrTime_1.75	Completed	20 of 20	Random.Triangular(52,55,58)	Random.Exponential(1.75)	82.2799	79.3539	7.92922	3.16054
Time2.75_Machine	Completed	20 of 20	5	Random.Exponential(2.75)	49.2664	47.4574	2.40414	0.513306
Time1.75_Machine	Completed	20 of 20	5	Random.Exponential(1.75)	82.5806	78.8995	10.3908	3.89903
Time_2.25	Completed	20 of 20	random.triangular(52,55,58)	Random.Exponential(2.25)	57.9017	58.2748	3.23581	0.84615
Time_2	Completed	20 of 20	random.triangular(52,55,58)	Random.Exponential(2)	72.4611	70.8607	5.89792	1.9584

Figure 3. Graphical Comparison of Performance Metrics Across Scenarios

Service	Average Customers/Month	Typical Service Time
Car polishing	10	30 minutes wash + 1-2 days polish
Interior detailing	20	1-2 days
Ceramic coating	2	2 days, but workers not required day 2
Car wash	55	30 minutes
Headlight & leather restoration	1	1 hour

Table 1. Standard Services, Frequency, and Duration

Scenario	Customer Interarrival Time (hours)	Cloth-Cleaning Time (minutes)	Customer Average Waiting Time (hours)	Service Area Capacity Utilization (%)
1	2½ (often seen)	Uniform between 52 and 58	3.2	58
2	2¾ (often seen)	Uniform between 52 and 58	2.4	54
3	3 (often seen)	Uniform between 52 and 58	1.7	46
4	2¼ (plausible)	Uniform between 52 and 58	3.3	58
5	2 (hopeful)	Uniform between 52 and 58	5.9	72
6	1¾ (aspired to)	Uniform between 52 and 58	7.9	79
7	2¾ (often seen)	5	2.4	47
8	1¾ (aspired to)	5	10.4	79

Table 2. Results Comparing Cloth-Cleaning Methods Under Different Arrival Rates