PARALLEL QUEUE OPTIMIZATION THROUGH COMPUTER AIDED SIMULATION AND QUEUEING THEORY - A CASE STUDY ON MATTA CANTEEN OF SABARAGAMUWA UNIVERSITY

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Abstract – A greater awareness and higher use of simulation technology caused many recent advances in the industry. ARENATM is a commonly used and convenient modeling and animating tool in the industry. It is grounded on object-oriented programming concepts and hierarchical modeling. Queuing is an obvious problem of the domestic canteens lacking the business philosophy of customer-centric in a market economy. When the simulation is over, we can find the model results and investigate the performance measures of our interest. As a case study, we selected the Matta Canteen of the Sabaragamuwa University of Sri Lanka. We simulated their process from 11.30 am to 1.30 pm. We applied the M/M/c queuing model for 2, 3, and 4 servers. The current system of 2 serving points has a 52.6 second waiting time in the queue, 3 serving points have 3.1 seconds and 4 serving points has 0.6 seconds. The average of customers waiting in the queue for the 2 serving point model is around 10 customers, but for the 3 serving point model, it reduced to 1 customer. According to our model, our recommendation is the 3 parallel servers to the current system. Our recommendation is further proved as the optimal model of the system using ARENATM and the queuing theory.

Keywords- Queue, Queueing Theory, Simulation, Food Serving, ARENATM

I. INTRODUCTION

Today, customers are much more conscious of cost perspectives before they choose a service or product. Performance metrics such as waiting time and activity costs are crucial for delivering a good-quality service at competitive prices. Generally, analytical tools are used to make decisions on staffing and pricing for a customer service process. But those tools have failed to consider the randomness and the system dynamics which are key parameters for queuing and variable costs analysis (Tumay, 1996).

Matta canteen is one of the main canteens which belong to Sabaragamuwa University of Sri Lanka. It is situated at the centre of the four faculties in the Sabaragamuwa University of Sri Lanka. Matta canteen caters breakfast, lunch and sometimes dinner for all the 7 days except some holidays. Further, they provide beverages like tea, plain tea, soft drinks etc. and short eats such as different bun varieties, mixture, vegetable rotti etc. in their open hours. They serve foods to students, academic staff, and non-academic staff. They provide dine in as well as take away services too. Approximately 2500 students, 300 academic staff members, and 250 non-academic staff members get a service from the Matta Canteen daily.

Queuing theory is concerned with the issue of waiting in the queue. Waiting is tedious and it should be avoided as it reduces the productive time of everyone within the system. Customers arrive to receive service by servers. Between arrival and start of service, there is a waiting time in the queue. Queues arise when the short-term demand for service exceeds the capacity of the server. It is most often caused by random variation in service times and the times between customer arrivals. Queuing and waiting time analysis is particularly important in service systems in order to improve their services which can attract more customers (Kelton et al., 2002).

Computer simulation tries to mimic real-scenario or hypothetical behavior on a computer in order to check how processes or systems can be improved. It also helps predict their performance under different circumstances and hypothetical scenarios (van der Aalst, 2010). Although simulation is typically considered as relevant and highly applicable to the real problem, but in reality, the use of simulation is limited. Most of the organizations have made an attempt to use simulation at some level in order to analyze their business processes. However, a very few are using simulation in a structured and effective manner (Van der Aalst et al., 2010).

By enabling enterprise-wide process simulation, ARENATM represents a most sophisticated advancement in simulation technology. It is a detailed system that takes into account all phases of a simulation project which starts with input data analysis to the output data analysis (Hammann and Markovitch, 1995). An impact on the various elements on the modeled system with different scenario combination could be analyzed using simulation. ARENATM assures a high degree of flexibility, various facilities for models of any level of complexity (Teilans et al., 2008). The modeling and executing system in ARENATM has the advantage of using the scaled formal layout of the real system.

II. LITERATURE REVIEW AND RELATED WORKS

ARENATM is a convenient modeling and animating tool that is based on concepts from object-oriented programming and hierarchical modeling. This kind of modeling tools is used by the second large community of system modelers. ARENATM is based on the SIMAN simulation language. It can be used for simulating different discrete and continuous systems in manufacturing, supply chain management, logistics, storing and other industries (Hammann and Markovitch, 1995).

The queuing theory is also widely using the historical random system theory, which examines the content of the system in the following three parts; (i) Behavior problems which mean that the queues probability is studied. It mainly deals with the queues, the length of distribution, and the waiting time distribution. Further, the busy period distribution is also looked into in both transient state and steady-state, (ii) Optimization problem which can be divided into the static optimization and the dynamic optimization. The static optimization problem is the optimal design, the dynamic optimization problem is the best operation of the queuing system and (iii) The statistical inference of queuing system is the third part that the robust model of a specified queuing system is determined for further investigating and analysing the queuing system (Xiao and Zhang, 2010).

In the study in "Solving waiting lines models in the airport using queuing theory model and linear programming the practice case" (Mehri et al., 2006), authors have conducted a case study on Tunisair Company at A.I.M.H.B during its' rush hour. They investigated the three parts of a queuing system (i) the inputs to the system, (ii) the queue or the waiting line, and (iii) the service readiness. After computing all the simulation results, the total expected costs are also studied by the authors. The total costs in their sense are the sum of the cost of providing service plus the cost of waiting time. By using these results they provided a feasible and profitable solution for the airline owner.

Ataeepour and Baafi (1999) showed in their research work, showed that ARENATM simulation models clearly show an enhancement of mine productivity with a dispatcher, especially when the truck fleet size is around the optimum value by using the Expected Delay Time concept. De Bruin et al. (2007) investigates the bottlenecks in the emergency care chain of cardiac in-patient flow. Their primary goal is to determine the optimal bed allocation over the care chain given a maximum number of refused admissions.

In "Modeling and simulation of emergency services with ARIS and Arena. Case study: the emergency department of Saint Joseph and Saint Luc Hospital" (Wang et al., 2009), authors have tried to solve the problem of overlong waiting time in emergency services which has the negative influence on healthcare quality. They resolved this by improving emergency services using modeling and discrete event simulation of the system process. They used IDS Scheer ARISTM and Rockwell ARENATM for their modeling purposes.

PROCEEDINGS

III. THE CURRENT PROCESS AND PROBLEMS FACED

Since Matta Canteen is located in the middle of the four faculties, most of the students, academic staffs, and non-academic staffs use this canteen for buying meals daily. More specifically for the students, Matta canteen is the key cafeteria for their meals. A considerable number of students usually come to Matta canteen on and on, especially in lunchtime (11.30 am to 1.30 pm). The lunch break usually falls between 12 - 1 pm and students have to walk a long distance to find another canteen to eat. This results in most of the students depending on Matta canteen for their having their lunch. Within the given short period, approximately 1 hour or 1 and a half hours, Matta canteen has to serve around 1300 students daily. Figure 1 shows the location of Matta Canteen.

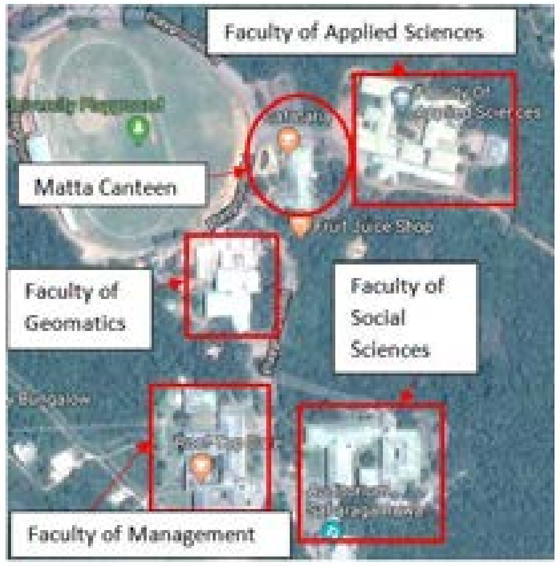

Figure 1. Map of Matta Canteen

Currently, the catering services are served by two service counters. After students get served from the service counters, they have to leave from the service counters and have their lunch by sitting in the seats available in the canteen. In our project, we are going to simulate the current situation and find alternative options, if they have 3 service counters and if they have 4 service counters for an effective service. Further, we are going to analyze the pros and cons of each three cases with the assistance of the computed results from the ARENATM simulation and by hand simulation. The Illustration of the current process is shown in Figure 2.

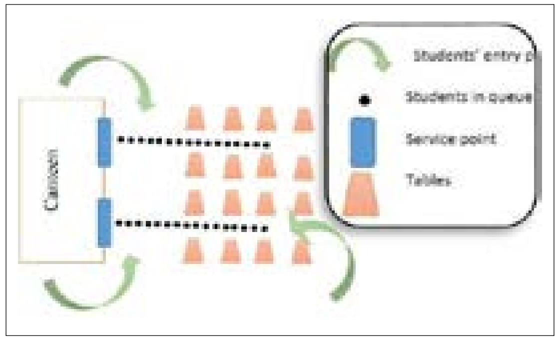

Figure 2. The current Process

For the time being, we took 11.30 am to 1.30 pm for our simulation because it is the most crucial time where students normally get rushed. Furthermore, there is a need for a proper solution in order to avoid the undesired consequences such as students miss the lunch due to long queues in a given short lunch break. Problems identified are; (i) There is a very long queue in the canteen very often, starting from the service counter to next end of the canteen, (ii) Students miss the lunch, and (iii) Students have to wait for a long time to get their meals. Therefore, because of the above-said problems, the aim of this work is to contribute to an improvement in the management of Matta canteen of the Sabaragamuwa University of Sri Lanka in order to reduce the waiting times for the students, academic and non-academic staffs.

IV. METHODOLOGY

As a first step for our simulation, we went to the Matta canteen and observed the process for a week (Monday to Friday). Currently, they are serving with two serving counters during the lunch hour. Based on our observations, we found that the queuing problem occurred during the time interval of 11.30am to 1.30pm. Therefore, we planned to simulate the canteen for that period. Then we analyzed those data gathered during the selected period to find the average inter-arrival time and average service time for a customer.

As a next step, we simulated the processes in the canteen by using the ARENATM Simulation Software. The advantage of using ARENATM was that the prior developed templates in various problem domains were readily available in it, and the reusability can be obtained. This means unlike conventional simulation systems in which all the modeling are hard-coded into the software by the vendor, ARENATM utilizes only soft-coded information which provides end users a freedom for reusable. We chose ARENATM because of these functionalities (Hammann and Markovitch, 1995).

Further, we applied queuing theory (Cooper, 1981, Gnedenko and Kovalenko, 1989) with M/M/c model with 2 servers, 3 servers, and 4 servers cases in order to verify with the ARENATM reports. Some notations used in the queueing theory are;

- λ : Mean rate of arrival.
- µ : Mean service rate.
- P = λ/µ: Utilization of the server.
- c : Number of servers.
- Pn : The probability of where n customers in the system.
- L : Average customers in the system.
- Lq : Average customers in the queue.
- W : Average time spent in the system.
- Wq : Average time spent in the queue.

When the mean service rate for each busy server is a constant for n all 1≥n, it is symbolized by µ. Here, when all c servers are busy, µn = sµ. Therefore, the expected inter-arrival time is 1/λ, the expected service time is 1/µ. Also, ρ = λ/(cµ) is the utilization rate for the service facility, i.e. the expected fraction of time as the individual servers are busy because λ/(cµ) represents the fraction of the system service capacity (cµ) that is being utilized on the average by arriving customers λ. The equations used in the M/M/c model is shown in table 1.

Table 1. M/M/c model equations

[illegible] = [illegible] (µ*c)
P_0 = 1 [illegible] $\sum_{i=1}^{} ci$
L = [illegible]W
L_q = [([illegible]µ)ᶜ [illegible] [illegible]C!(1-[illegible])²] * P_0
W = (Wq +1) [illegible]µ
W_q = L_q[illegible]

V. RESULTS AND DISCUSSIONS

Table 2 shows the results [illegible] M/M/c queueing model for two, three and four se[illegible]es for Matta canteen.

Table 2. M/M/c model outcomes with 2,3,4 servers

	C = 2	C = 3	C = 4
Average customers in the queue (L_q)	9.6449 customers	0.58 customers	0.1147 customers
Average customers in the system (L)	11.4783 customers	2.4134 customers	1.948 customers
Average time waiting in the queue (Wq)	0.8768 min (52.6087 sec)	0.0527 min (3.1638 sec)	0.0094 min (0.6257 sec)
Average time spent in the system (W)	1.0435 min (62.6087 sec)	0.2194 min (13.1638 sec)	0.1522 min (10.6257 sec)

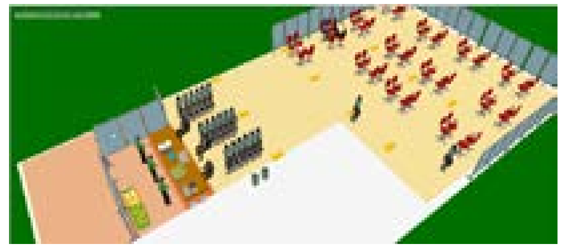

Figure 4. 3D view of Matta Canteen three server counters

The current system of two serving counters has 52.6 seconds waiting time in the queue, three serving counters have 3.1 seconds and four serving counters has 0.6 seconds. By using this results we suggest that the current serving counters can be improved to three serving counters as the waiting time goes down drastically by 48 seconds.

Further, even though four serving counters reduce the waiting time up to around 2.5 seconds from three service counters to four service counters, it is not efficient to go for four serving counters because the cost to create a 4th serving counter cannot be overcome by reducing the waiting time.

Further, average customers in the queue also get drastically reduced. For the two serving counters model there are around 10 customers, but for three serving counters model it reduced to 1 customer. So three serving counters model will be the most efficient than two serving model.

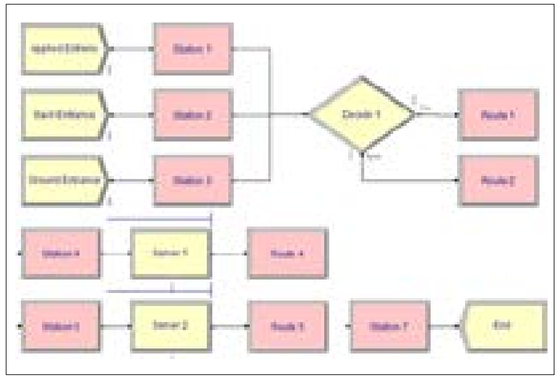

Figure 3. The layout of Matta Canteen for two serving counters

The assumptions used for analyzing the waiting lines are; (i) Customer arrivals into the system is Poisson distributed, (ii) Customer arrivals into the system come from an infinite population, (iii) Customer arrivals into the system are treated on a first in first out (FIFO) order and do not pause or revoke, (iv) Service times follow the negative exponential distribution or are constant, and (v) The average service rate is faster than the average arrival rate (Mehri et al., 2006).

The simulated results of the ARENA™ show that the three serving counters are more effective than the two serving counters. Figure 3 shows the layout and the process of the Matta canteen for two serving counters in the ARENA™ design view.

3 dimensional (3D) view of the simulated canteen at one particular time (at one instance) for three service counters is shown in figure 4 and two service counters is shown in figure 5.

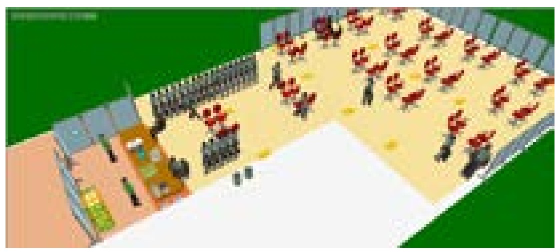

Figure 5. 3D view of Matta Canteen 2 server counters

V. CONCLUSIONS AND RECOMMENDATIONS

Waiting lines and service systems are crucial indications of an effective service in the business world. In this study, the alternative ways of reducing the customers waiting time are studied using the queuing theory and simulation through ARENA™ simulation software. The measure to reduce the time of customers' queues is obtained to achieve the goal of delivering good quality and effective service at the Matta canteen. According to the results we obtained through both queueing theory and ARENA™, the current method used by canteen i.e. two service counters can be improved to three service counters because the waiting time drops drastically when compared to two service counters. ARENA™ delivers an integrated framework for building our simulation models conveniently and effectively.

Our future plans go as simulating for the Matta Canteen for a whole day of their working time i.e. 6.30 am to 6 pm. And also we are planning to do the cost estimation for our simulated results in order to strengthen our recommendations.

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