1) INTRODUCTION:

Like some of the administrative offices inside the university, the Graduate School of the University of Connecticut (at Storrs campus) needs a more efficient system when getting its jobs done. One of the major responsibilities of the Graduate School is the registration of students which occurs twice a year, one for Fall and one for Spring semester. Registration for summer, generally speaking, does not put too much pressure on Graduate School, and therefore, is not included in this paper.

This paper will focus on the last two weeks of August when the registration for Fall semester reaches its peak time. I believe that the administration is not much knowledgeable about the number of students they are serving in one day; so, they are not able to predict how many people they should use at that time period.

Basically, the inefficiency occurs at that stage since unnecessarily big number of personnel work on the process. On the other hand, when Graduate School notices this inefficiency, it puts insufficient number of people for registration and so, students spend a lot of time on the line. As an example, during morning hours, students mostly wait on the line and waste their time while afternoons, three sometimes even four workers sit idle.

The purpose of this project is not to bring a brand new and sophisticated solution. Nevertheless, the aim is to bring "Queuing Model" and "Simulation Technique" together to observe a real-life problem and to come up with recommendations.

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2) METHODOLOGY:

First, I will use an analytical approach, Queuing Model, to get the numbers regarding the waiting time and the total number of students in the queue and in the system.

Following this, I will build two different simulation models with XCELL+ simulation program which are actually very close to current registration process so that I will be able to see our output -which is the number of students in that case-.

Finally, I will bring these results together and give some recommendations.

3) PERFORMANCE MEASURES:

From the point of view of Graduate School, the objective is the highest achievable efficiency. Therefore, the prioritized performance measure is the number of personnel. It would be costly for Graduate School if some employees sit idle while other administrative things wait to be done.

Other performance measures can be given as:

- The number of students waiting.
- The waiting time of students.
- The number of students in the system.
- Budget constraints (as it is given above, it is to best interest of Graduate School to put the right number of people on the registration process).

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4) DATA AND ASSUMPTIONS:

The only useful data I could collect is the total number of graduate students at Storrs campus. In Fall 1994, a total of 4,503 students registered -4,045 degree seeking and 458 non-degree students.

Unfortunately, Graduate School was unable to provide me more information. Therefore, to come up with an analytical analysis, I had to make some assumptions. Accordingly, it is assumed that there are 40 students arriving, and 24 students being served per hour. Both the student arrival time and the service time are exponentially distributed.

5) QUEUING MODELS:

-- Queuing discipline: FIFO.

-- 40 students/hour arrive => $\lambda=2/3$.

-- 24 students/hour being served => $\mu=0.4$.

5.1) M/M/2 MODEL:

-- $\rho = \lambda / (s \times \mu) = (2/3) / (2 \times 0.4) \cong 0.833$.

-- $P_0 = 1 / \left[\Sigma [(s \times \rho)^i / i!] + [(s \times \rho)^s / (s!) \times (1-\rho)] \right] \cong 0.1$.

-- $P(n \geq s=2) = [(s \times \rho)^s \times P_0] / [(s!) \times (1-\rho)] \cong 83.1\%$.

-- $L_s = (s \times \rho) + [(s \times \rho)^{s+1} \times P_0] / [(s) \times (s!) \times (1-\rho)^2] \cong 5.81 \approx 6$ students.

-- $L_q = [(P_0) \times (s^{s+1} \times \rho^{s+1} / s)] / [(s!) \times (1-\rho)^2] \cong 4.15 \approx 4$ students.

-- $W_s = L_s / \lambda \cong 8.72$ minutes.

-- $W_q = L_q / \lambda \cong 6.23$ minutes.

5.2) M/M/3 MODEL:

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Using the same formulas above, the results become:

-- $\rho \cong 0.556$.

-- $L_q \cong 0.46 \approx 1$ student.

-- $P_0 \cong 0.21$.

-- $W_s \cong 3.2$ minutes.

-- $P(n \geq s=3) \cong 36.58\%$.

-- $W_q \cong 0.7$ minute.

-- $L_s \cong 2.13 \approx 2$ students.

While the Queuing Model gives us some figures regarding some of the performance measures such as the students' waiting time and the total number of students, we need to build a Simulation Model also to compute our output. Therefore, in this problem, Queuing Model and Simulation Model are complementary.

Simulation Model also helps us develop "what if" scenarios, i.e., how many students we could serve with two servers, three servers, etc. However, since the prioritized performance measure of Graduate School is the number of people they employ, XCELL+ is much more helpful to get concrete results. My point of view is that rather than focusing on the number of students waiting or how much time they spend, Graduate School logically concentrates on its own personnel.

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6) SIMULATION MODELS:

As it is given before, the purpose of XCELL+ simulation model is to see a possible average output and by the help of this output, decide whether and when 2-server or 3-server system should be used. Besides, seeing an output proves whether our analytical approach is consistent.

But most of all, thanks to XCELL+ models, Graduate School would be able to increase
the number of servers during a particular peak time period such as morning hours and to reduce them again during afternoon hours.

7) <u>THE MODELS:</u>

Basically, we have two different models: **2-server** and **3-server** systems. However, there is one more workstation where the gold cards of students are processed and placed into the folders. We will also have a dummy workstation after the receiving area so that all of the students will not arrive to the servers at the same time. In other words, dummy workstation just plays an organizer role.

We do not have any triggering mechanism. We have two buffers, one between the dummy workstation and servers, and the other between the servers and the last workstation where cards are processed.
There are 8 hours in one working day, and the models will be run for 10 days.

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7.1) <u>MODEL 1:</u>

Receiving area: Unlimited (since the number is too big -4,503 students-, “unlimited” is preferred).

Dummy workstation: No setup time. No processing time. Batch size of 30.

Workstations 2 and 3: No setup times. Processing times: [Exponential, 2.5].

Workstation 4: No setup time. Processing time: [Uniform. Min., Mean., Max.: 0.50, 1.00, 1.50]. Batch size of 30.

Buffers 1 and 2: Capacities are 60 and 100 respectively. FIFO.

Shipping area: Continuous shipment.

Maintenance area: Assigned for workstations 2 and 3.

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7.2) <u>MODEL 2:</u>

Virtually everything is the same with Model 1 except that we have three servers after the first buffer, and the third workstation’s setup and processing times are the same with the first two servers’. Also, the maintenance area serves these three servers as opposed to serving two servers of the first model.

8) <u>COMPARING TWO SYSTEM DESIGNS:</u>

$H_0: \mu_1 - \mu_2 = 0$.

	Model 1	Model 2
Mean	370.10	479.50
Variance (s^2)	538.24	7.62
Standard Deviation (s)	23.20	2.76
n	10	10

Using α=0.05, let us test the hypothesis that the mean number of students registered per day for the second model is no different from that of the first system.

(1-α) confidence interval: $(Y_{.1} - Y_{.2}) + (t_{\alpha/2,v}) \times (\text{St. Dev. } Y_{.1} - Y_{.2})$.

St. Dev. $(Y_{.1} - Y_{.2}) = [(s_1^2 + s_2^2) / n]^{1/2} \cong 7.39$.

$v = \Big[[(s_1^2 + s_2^2) / n]^2 / \big[[(s_1^2 / n)^2 + (s_2^2 / n)^2] / (n+1) \big] \Big] - 2 \cong 9.31$.

$t_{0.025,9} = 2.262$.

$(Y_{.1} - Y_{.2}) = -109.4$.

Upper limit for (1 - α) confidence interval $\cong$ -92.68.

Lower limit for (1 - α) confidence interval $\cong$ -126.12.

----[--------------●--------------]----------------●--------

-126.12 $(Y_{.1} - Y_{.2})$ -92.68 0

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This suggests that with 95% confidence, $\mu_1 < \mu_2$ and we reject the null hypothesis. So, we come up with the result that the performance measure -the mean number of students registered per day- for the second system is different from that of the first system.

The confidence interval to the left of zero suggests that the average number of students registered per day is significantly higher in Model 2 when compared with Model 1. Hence, the second model provides better performance measure for the Graduate School.

9) RECOMMENDATIONS:

Because the Graduate School was unable to provide me all the data I need, I am not able to give exact results, such as which model should be used. However, I believe, the results are useful to show Graduate School administration their performance measures. I also believe that even though I am not able to provide exact solutions, the models can be beneficial for the Graduate School administration to figure out what output they will get when using two different systems.

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To support the results and my models, I make the following recommendations:

a) Students with odd social security numbers can register in odd days, and with even social security numbers can register in even days of the month. This recommendation is only valid for the last two weeks of August which is the peak time. Students who do not follow these directions will pay a fee. Possible benefits of this recommendation are:

- Students will feel that they should not leave their registration in the last minute, hence, this will reduce the work load of Graduate School.
- Intuitively, the number of possible maximum students in one day will drop 50%, from 4,500 to 2,250, assuming that there is a fair and equal distribution in the social security numbers of students.
- The prediction regarding the number of students in one day can be more accurate. The assumption here is that by the time the number we deal decreases, it becomes easier to predict the behavior of students.
- The biggest advantage, I believe, is that after a couple of years of adoption time, registration process will be more organized.

One possible disadvantage is that the number of students in the last days even might increase. However, there are yet some students who register late and accept to pay the late registration fee which shows that exceptional behaviors are always possible.

b) Registration by phone: This will also reduce the work load of Graduate School. Like University of Massachusetts has been using, there can be a system where students who do not register by phone pay a fee.

c) Registration by mail: Currently, there are already a few students who register by mail in "Credit Program". I believe that if registration by mail is encouraged and made easier, that will also help Graduate School reduce its load and work more efficiently.

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APPENDIX

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UPPER AND LOWER LIMITS OF MODELS' RESULTS:

It is essential to find the upper and lower limits of the replications because Graduate School may want to know the optimistic and the pessimistic results regarding the number of students served in an average day. A t-distribution is used for this test.

Accordingly, our upper and lower limits with 95% confidence level become:

	Upper Limit	Lower Limit
Model 1	386.70	353.50
Model 2	481.47	477.53

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THE RESULTS OF THE SIMULATION MODELS:

Replications	2-Server System	3-Server System
1	337	481
2	336	482
3	345	475
4	397	475
5	374	479
6	375	483
7	380	479
8	384	479
9	373	480
10	400	482
Cumulative	3,701.00 students	4,795.00 students
Average	370.10	479.50
Standard Deviation	23.20	2.76

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