UNIVERSITY BOOK CENTER SIMULATION PROJECT REPORT

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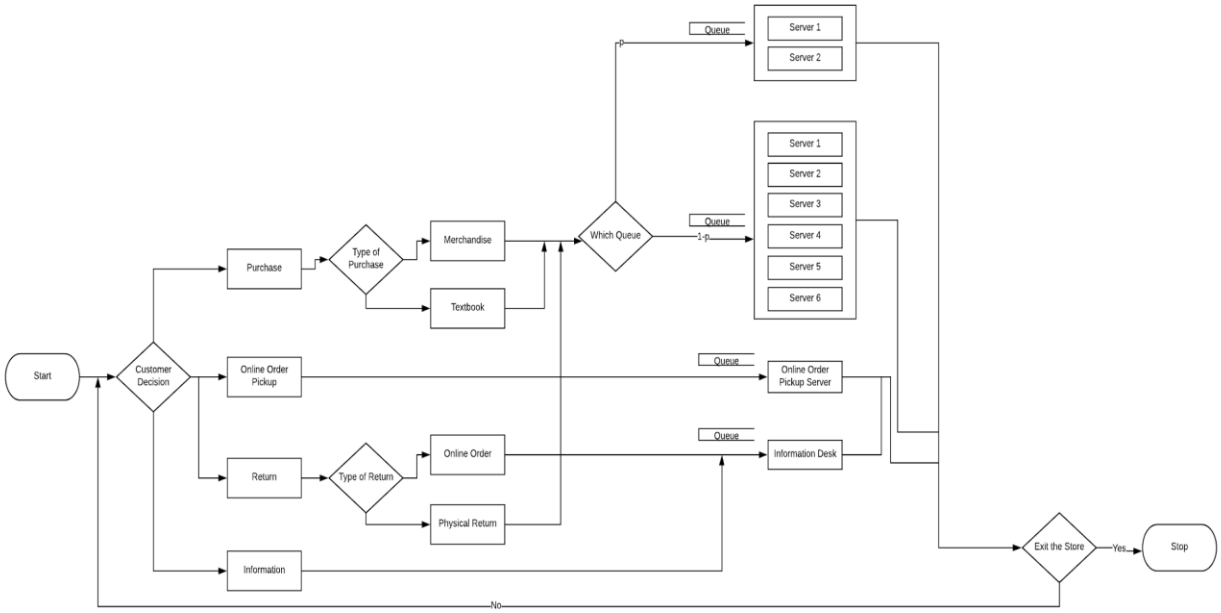
Description: Improve Productivity and Efficiency; Identify Bottlenecks

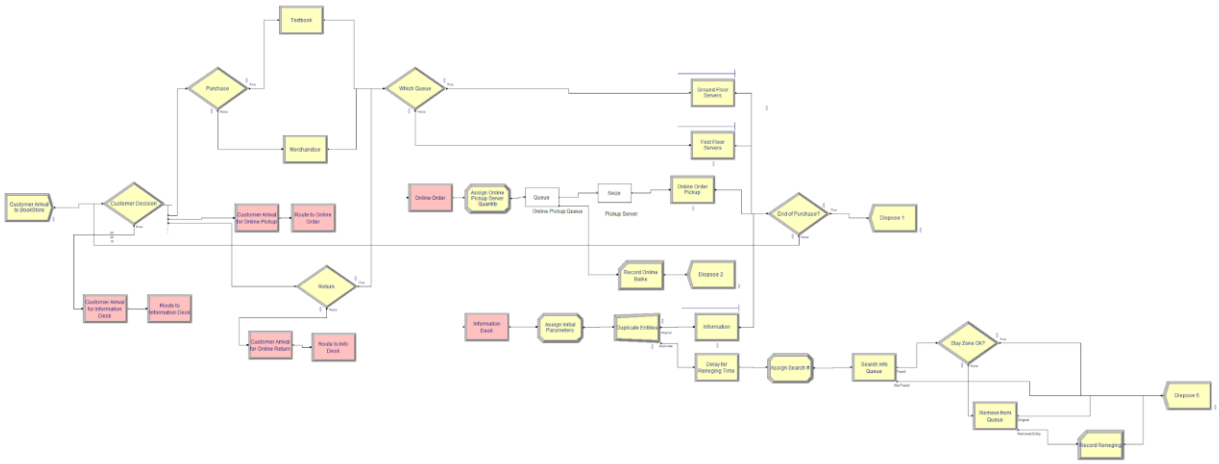
Barnes & Noble - The University bookstore is located in the STAMP Student Union building at the University of Maryland. Improving customer experience has always been a major business goal of the bookstore. Students across the University gather at STAMP during lecture breaks or after school hours, so the bookstore location is one which always remains crowded. Every year, students in large numbers rely on the bookstore for their primary education materials like textbooks and stationery. Along with education materials, the bookstore also sells official University merchandise and novels that are always in high demand. Students are primary customers of the bookstore and Barnes & Noble often find it difficult to ensure smooth transitions of customers through the store. Students face long queues and high service times during peak hours of the day that is from 11 pm to 3 pm and often visit the bookstore multiple times to fulfill their needs. During the beginning of every semester, Barnes & Noble experience an excessive demand among students and are therefore forced to hire a large number of staff members on a part-time basis. As the semester progresses, Barnes & Noble start reducing staff members on a random demand estimation of the arrival of customers.

Flowchart:



The flowchart shown explains all the possibilities of decisions a customer can take after entering the store. The first decision made by the customer after entering the store is if they want to purchase, return, pick-up an online order or gather information from the information desk. The decision will be made on the basis of predicted probabilities. If the customer wants to gather information, they directly move to the queue for the information desk server and then exit the store. Similarly, if the customer wants to pick-up an online order, they move directly to the queue for the online order pickup server. Further, they can make decisions to either purchase or return an item. If the customer decides to purchase an item, they have to make a decision to either purchase a textbook or merchandise. Once the items are selected from the store the customer goes to the checkout queue for billing. There are two queues for the checkout line; Level 1 and Level 2 of the store correspondingly. Level 1 is equipped with 5 servers for the billing functionality while level 2 is equipped with 2 servers for the same purpose. This decision is made by the customer mostly depending on the item bought, but in this case, the customer purchasing a merchandise item is highly probable of going to level 2 queue. Lastly, if the customer wants to return an item they can move directly to the queue for the information desk if its an online order return or else the customer can move to the queues allocated for billing servers. The feedback loop provided takes into account the possibility that a customer can go back and purchase more items if they wish to.

A description of the model implementation in Arena, including what flowchart and data modules are used, what output measures are produced, and any other relevant features



Basic Process:

Create, Dispose, Process, Decide, Assign, Record, Attribute, Entity, Queue, Resource, Variable, Set

Advanced Transfer:

Route, Station, Station Data

Advanced Process:

Delay, Remove, Search, Expression

Statistics:

Counter

We have used the Set Module to account for the difference in service times between experienced and non-experienced servers on first-floor and ground floor. Experienced Servers have on average lesser waiting time than non-experienced servers. The Route and Station modules are used to account for the transfer time of customers as they walk through the bookstore from one place to another. Record module help in counting the number of customers that end up reneging or balking.

Description of Inputs:

1. **Customer inter-arrival time -** The inter-arrival time for customers follow an exponential distribution with a mean of 0.45 minutes

2. **Server processing time -** We have allocated different server processing times based on the experience level of different cashiers. Some servers are fluent with the system interface and hence take less time to process customers as opposed to others.

   Ground Floor Servers:
   Server 1 - TRIA (2,2.9,3.4)
   Server 2 - TRIA(1.2,2.1,2.6)
   Server 3 - TRIA(2.8,3.9,5.2)
   Server 4 - TRIA(1.8,2.3,3.6)
   Server 5 - TRIA(3.3,4.1,6.3)

   First Floor Servers:
   Server 6 - TRIA(2.2,2.9,3.8)
   Server 7 - TRIA(2.5,3.3,4.7)

   Information Desk Server: TRIA(3.1,5,15)

   Online order pick up Server: Normal(1.5,0.4)

3. **Delay -** The delay is experienced during purchase of textbook and merchandise. When a customer purchases a textbook, the model accounts for the delay in selecting a textbook of 5 minutes. Similarly, when a customer purchases merchandise, the delay time for selection of design/size it takes 7 minutes on average.

4. **Probabilities -** We determine the decisions taken by customers at different stages in the model using probabilities as below.

   Decision 1: Customer Activity Decision
   - Purchase: 65%
   - Online order pick up: 20%
   - Return: 10%
   - Information: 5%

   Decision 2: Purchase Textbook or Merchandise
   - Textbook: 80%
   - Merchandise: 20%

   Decision 3: Queue selection after purchase
   - Ground floor: 75%
   - First floor: 25%

Decision 4: Return item decision

- Physical purchase return: 95%
- Online purchase return: 5%

Decision 5: Stay zone decision

- Tolerant to a small change in threshold value: 60%
- Non-Tolerant: 40%

Decision 6: Exit store

- Yes: 90%
- No: 10%

5. **Setup Parameters** -
   Number of Replications: 20
   Warm-up Period: 0.0
   Replication Length: 1day
   Hours Per Day: 4 hours

Simulation Experiments:

We experimented with our model and we followed these observations

1. **Model Implementation without Balking and Reneging**
   Initially, our model consisted of customers that did not account for the balking and reneging possibility due to the length and waiting time of queues. We observed the waiting times for the queues to be exceptionally high. However, we figured the system was far away from a practical model.

   Average waiting times:
   Ground floor waiting queue: 6.38 minutes
   First-floor waiting queue: 6.23 minutes
   Information desk waiting queue: 8.87 minutes

2. **Model Implementation with Balking and Reneging**
   To replicate a practical simulation model and to account for the customer's urge to leave, we implemented the model with balking for Online order pick-up queue and reneging for Information desk queue. We saw significant improvement in the average waiting time of information desk queue and it was closer to the practical waiting times observed during peak hours.

   For balking, we have used a TRIA(1,2,3) distribution. This implies customers would balk when there are more than 2 customers waiting in line before them. The total balks in the peak period are recorded.

For reneging, the Renege Time follows a TRIA(1.5,1.8,2.1) distribution. The probability of a customer staying in the Stay Zone follows a POIS(1.5) probability and 60% of the time customers would agree to remain in the Stay Zone. The number of customers who reneged are also recorded.

The model is implemented with balking and reneging and the final results are attached below. Please refer to the summary report screenshots attached for detailed information.

An analysis of the overall performance of the system:

From the below graphs and summary statistics, we can identify the following:

1. Bottlenecks - The average waiting time for the first floor, ground floor, and information queue experience the highest average waiting time and is responsible for the bottlenecks in the system. These bottlenecks should be the main focus of management and we have focussed on reducing the waiting times to ensure a satisfactory customer experience.

2. Productivity - The utilization rates for all individual resources along with graphs are also shown below. We can observe that all of the servers are busy for the majority of the duration of simulation and hence idle time is very less. This means that during peak hours, our servers are productive. This is further strengthened by the fact that each server has high utilization rate.

3. Efficiency - Resource 1, Resource 4, and Resource 6 are our experienced servers and hence account for seizing the maximum number of customers as expected due to their faster service times.

4. Balking - An average of 35 customers tend to balk and exit the queue when a large number of customers precede him/her waiting in the queue for online pickup.

5. Reneging - From our results, we can deduce 11 of our total customers arriving at information desk queue tend to renege when the waiting time exceeds their tolerance threshold.

Queue

Time

Waiting Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
First Floor Servers.Queue	6.7184	1.81	1.5096	14.8626	0.00	30.6780
Ground Floor Servers.Queue	6.8786	2.24	0.9371	16.7925	0.00	30.1134
Information.Queue	5.9203	1.58	1.6634	12.9382	0.00	59.0418
Online Pickup.Queue	0.7521	0.04	0.6031	0.9373	0.00	3.9852

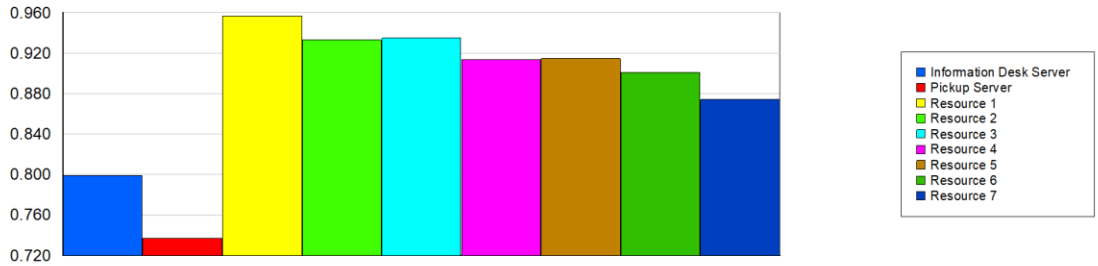
Other

Number Waiting	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
First Floor Servers.Queue	3.9875	1.14	0.7171	9.5767	0.00	20.0000
Ground Floor Servers.Queue	12.1866	4.15	1.3837	30.6521	0.00	53.0000
Information.Queue	1.0072	0.31	0.2053	2.5540	0.00	8.0000
Online Pickup.Queue	0.3725	0.03	0.2883	0.4620	0.00	2.0000

Resource

Usage

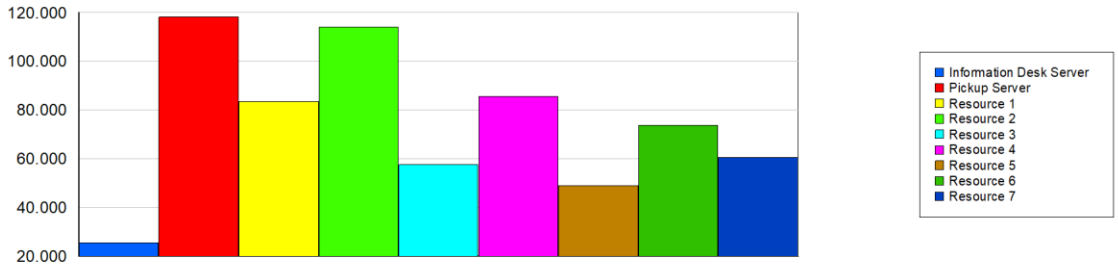
Scheduled Utilization	Average	Half Width	Minimum Average	Maximum Average
Information Desk Server	0.7990	0.05	0.5494	0.9738
Pickup Server	0.7371	0.02	0.6550	0.7960
Resource 1	0.9564	0.01	0.8893	0.9890
Resource 2	0.9329	0.02	0.8256	0.9770
Resource 3	0.9350	0.02	0.8476	0.9747
Resource 4	0.9132	0.03	0.7299	0.9737
Resource 5	0.9146	0.03	0.7654	0.9681
Resource 6	0.9006	0.02	0.7586	0.9687
Resource 7	0.8740	0.03	0.7044	0.9603



Resource

Usage

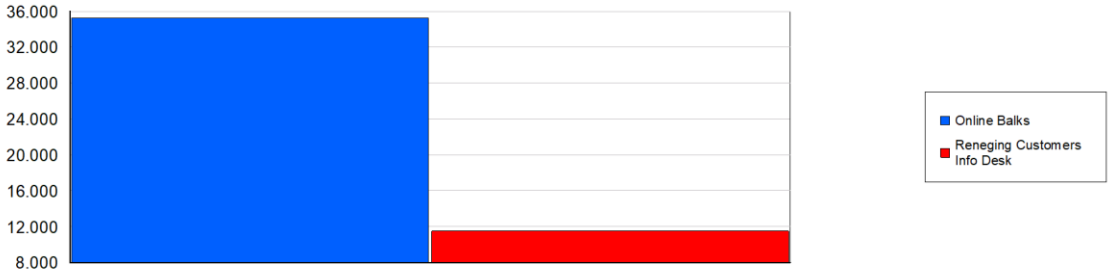
Total Number Seized	Average	Half Width	Minimum Average	Maximum Average
Information Desk Server	25.5500	1.45	19.0000	32.0000
Pickup Server	118.30	3.40	105.00	132.00
Resource 1	83.5500	1.26	77.0000	87.0000
Resource 2	114.15	2.65	99.00	120.00
Resource 3	57.5500	1.11	52.0000	61.0000
Resource 4	85.5000	2.59	71.0000	92.0000
Resource 5	48.9000	1.42	40.0000	53.0000
Resource 6	73.6500	1.93	64.0000	80.0000
Resource 7	60.5500	1.99	50.0000	68.0000

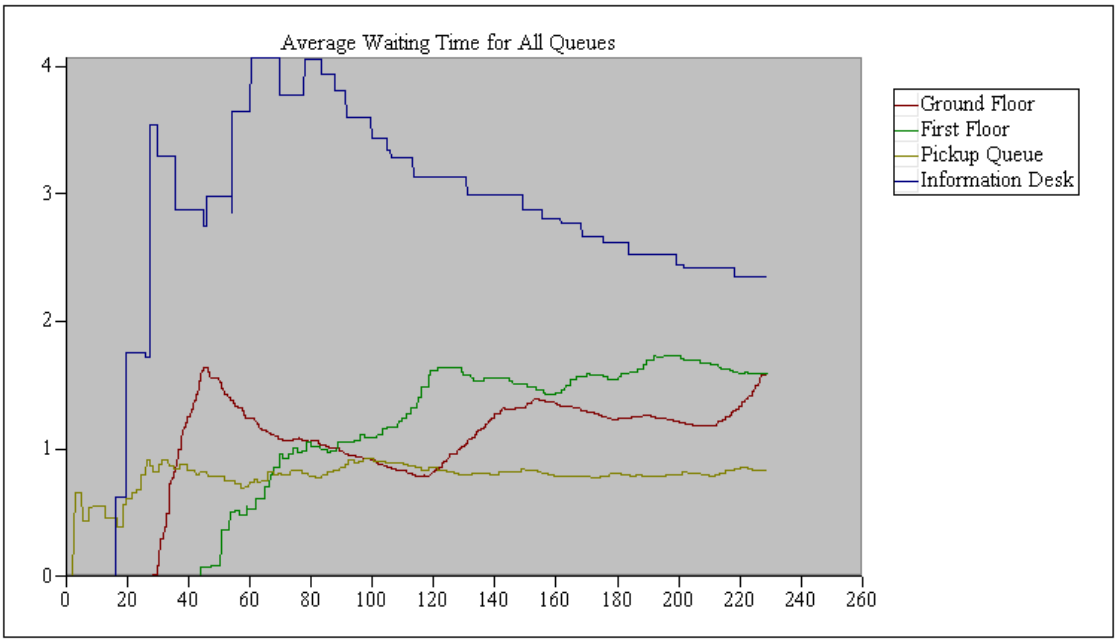


User Specified

Counter

Count	Average	Half Width	Minimum Average	Maximum Average
Online Balks	35.2500	3.44	19.0000	48.0000
Reneging Customers Info Desk	11.5000	1.83	3.0000	17.0000





The following graph represents the average waiting times for customers in all the queues. The Information Desk has the highest average waiting time. At the start of the peak hours, a lot of the customers visit the Information Desk to know about the different details. However, as time progresses the number of people in the Information Desk Queue reduces. Also, Ground Floor Queue and First Floor Queue have peaks and valleys in their average waiting time. Pick-up Queue waiting time is acceptable and is consistently less than 1 minute per customer.

An analysis of any potential improvements to the system and the resultant changes to the system if one or more of these improvements were implemented:

We would like to recommend two potential solutions to the bookstore management that will help improve the system as follows:

1. **Recommendation 1 - Schedule experienced cashiers during peak hours**
   According to our analysis stated above, our advice to management will be to only schedule experienced employees during peak hours. This will enhance service times of servers; which eventually leads to a significant decrease in average waiting time of the first floor and ground floor queues respectively from approximately 6 minutes to 2.20 minutes and 0.6 minutes respectively.

   As we can see in the resource detail summary that the utilization rate for all of the servers is still above 0.5 which means that even after employing experienced servers, they are not being under-utilized.

Queue Detail Summary

Time

	Waiting Time
First Floor Servers.Queue	2.20
Ground Floor Servers.Queue	0.60
Information.Queue	5.88
Online Pickup.Queue	0.50

Resource Detail Summary

Usage

	Inst Util	Num Busy	Num Sched	Num Seized	Sched Util
Information Des	0.84	0.84	1.00	24.00	0.84
Pickup Server	0.73	0.73	1.00	115.00	0.73
Resource 1	0.85	0.85	1.00	104.00	0.85
Resource 2	0.76	0.76	1.00	95.00	0.76
Resource 3	0.71	0.71	1.00	85.00	0.71
Resource 4	0.62	0.62	1.00	75.00	0.62
Resource 5	0.51	0.51	1.00	64.00	0.51
Resource 6	0.93	0.93	1.00	77.00	0.93
Resource 7	0.85	0.85	1.00	69.00	0.85

2. **Recommendation 2 - Increase Resources**

Our alternate recommendation to management will be to increase the number of resources on queues with the highest average waiting times; ground floor server, first-floor server, and information desk server queues. We recommend adding 1 additional resource to the first floor and information desk. Since the ground floor serves the majority of the customers, we propose the addition of 2 additional resources. This will help to serve more number of customers and hence reduce average waiting times while keeping the resource utilization rate to an acceptable level.

However, we would like to caution management, this solution will definitely be **Capital Intensive** and will strongly recommend this solution if the benefits match the required costs.

Queue Detail Summary

Time

	Waiting Time
First Floor Servers.Queue	0.61
Ground Floor Servers.Queue	0.17
Information.Queue	4.22
Online Pickup.Queue	0.71

Resource Detail Summary

Usage

	Inst Util	Num Busy	Num Sched	Num Seized	Sched Util
Information Des	0.72	1.44	2.00	44.00	0.72
Pickup Server	0.69	0.69	1.00	113.00	0.69
Resource 1	0.85	0.85	1.00	75.00	0.85
Resource 10	0.48	0.48	1.00	39.00	0.48
Resource 2	0.74	0.74	1.00	94.00	0.74
Resource 3	0.78	0.78	1.00	46.00	0.78
Resource 4	0.69	0.69	1.00	68.00	0.69
Resource 5	0.64	0.64	1.00	35.00	0.64
Resource 6	0.54	0.54	1.00	52.00	0.54
Resource 7	0.44	0.44	1.00	37.00	0.44
Resource 8	0.76	0.76	1.00	61.00	0.76
Resource 9	0.67	0.67	1.00	46.00	0.67

Conclusion:

After a thorough analysis of the University Bookstore model, we found that Ground Floor Servers, First Floor Servers and Information Desk Server are significant bottlenecks during the peak hours. Each of these resources have a healthy resource utilization however, they also showcase high waiting times. This implies that even though our allocated resources are utilized in an efficient manner, the servers are overworked i.e the assigned number of servers is not optimal. Thus, employing 5 servers on the Ground Floor, 2 on the First Floor and 1 as the Information Desk Server is clearly not enough.

We recommend the following solutions to remedy these problems. If money is not an issue, it would be highly beneficial to add an extra resource to each of the bottlenecks. Increasing the number of servers by one would alleviate the issue of high waiting times. Secondly, if cost is an issue, a workaround would be to assign only the experienced servers during the peak hours. This results in lower average waiting time for customers and faster turnaround time.