IŞIK UNIVERSITY

Faculty of Engineering

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System Simulation

Project Report

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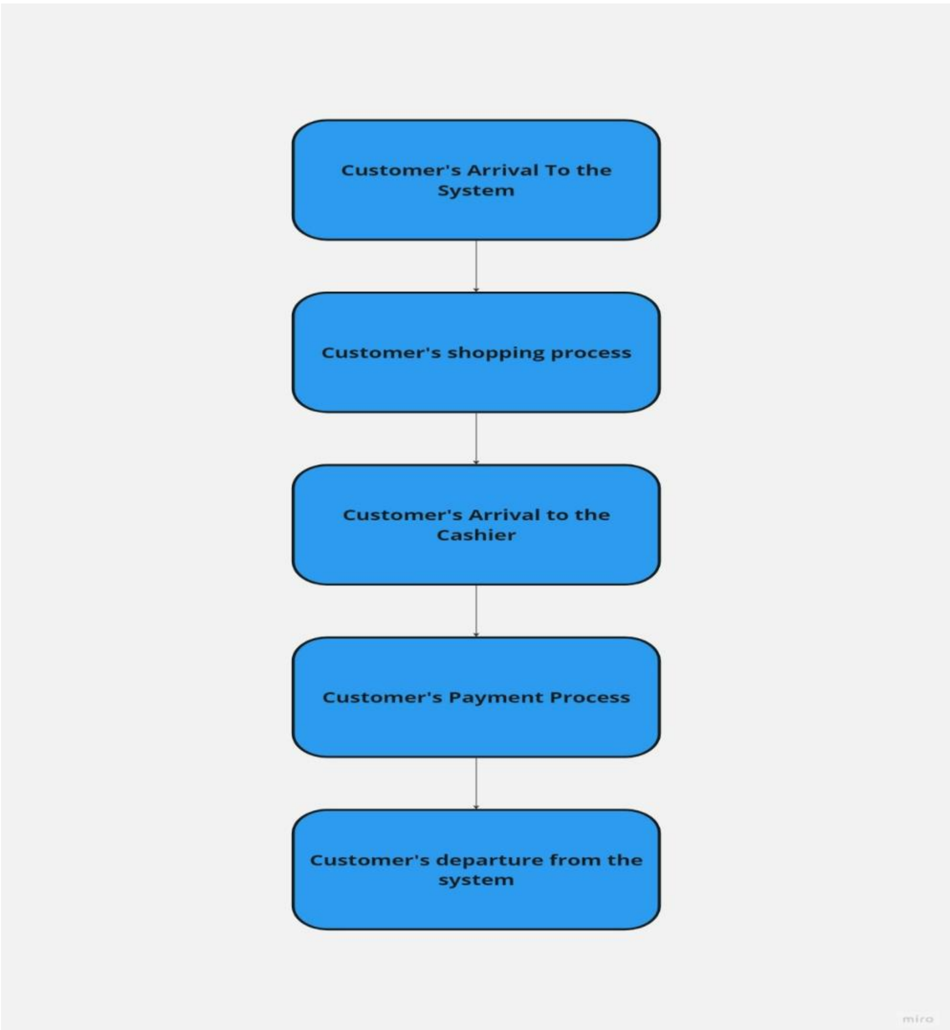
1. Introduction

This model is centered around data pertaining to the Şok chain market, specifically focusing on the branch situated within our university campus. Şok market caters to customers' fundamental household and personal needs. However, operational challenges arise, particularly during peak hours, leading to issues in service delivery. The primary concern revolves around congestion, negatively impacting sales figures. In the context of our simulation project, the challenge is pinpointed to queue lengths. We collected data during periods of high foot traffic, specifically after school hours, between 17:00-18:00. The root cause of this congestion stems from a bottleneck at the cashier, where a single cashier's capacity falls short during the surge in customer numbers at that specific time.

Our specific goal is to address the queue time issue, delve into its underlying causes, and propose enhancements to the system using Arena Simulation

1.1 Conceptual Model:



2. Modelling Assumptions:

- **Objective:** Our primary focus is on minimizing queue time, which we have in the system. The objective is to enhance the overall system performance by reducing the time customers spend waiting in queues.
- **Input Parameters:** The arrival time, queue time and service time.

Structural Assumptions:

- Data was observed from 17:00pm to 18:pm per day.
- We assumed that the system was idle when we started at 17:00 pm on Thursdays.
- While observing the market if people made their payment as a group, we count them as one customer.
- The customers enter the market and the one who finishes shopping will go to the queue first. Since we have one cashier there will be one customer on serve at that time.

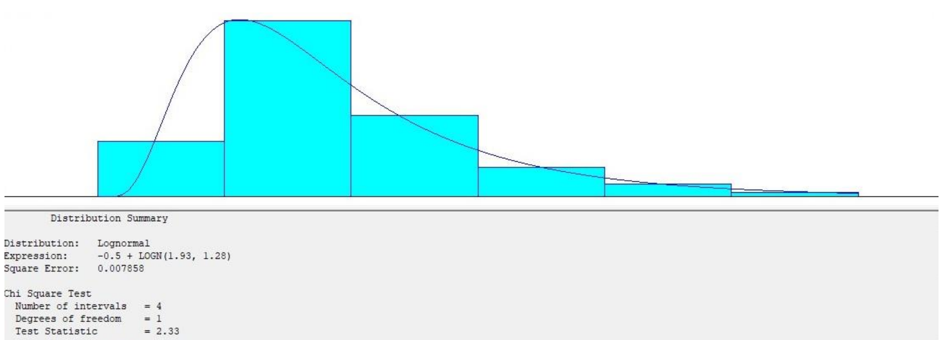
Data assumption:

- We observed each customer's arrival time, then when we fitted the data to Arena software we found the inter-arrival times with Lognormal distributed with a mean of 1.39.
- Lastly the service time is the process which has been done by the cashier. After fitting these datas to Arena software we found that it is Gamma distributed with a mean of 0.876.

2.1 Fitting statistical distributions:

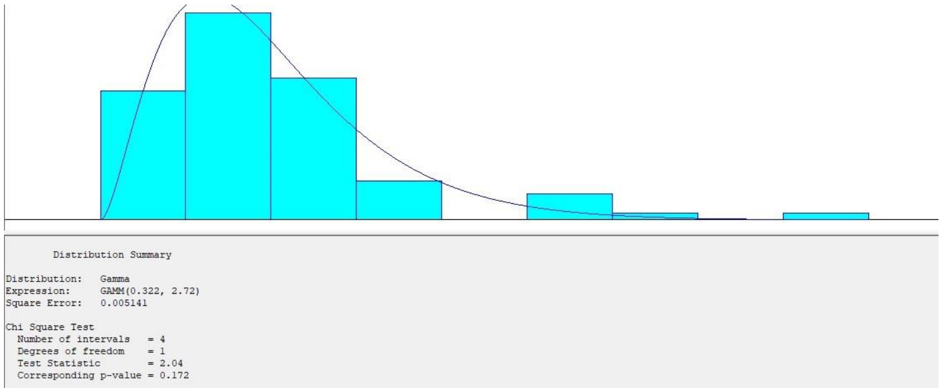
"Lognormal distributed && Gamma distributed.''

Interarrival Time:



After fitting the data interarrival time distribution can be seen as Lognormal distribution.

Service Time:



After fitting the data service time distribution can be seen as Gamma distribution.

2.2 Arena Model Output:

Discrete-Time Statistics (Tally)

Project Name	Name	Type	Source	Average Of Replication Averages	Observed=Requested	Half-Width	Minimum Replication Average	Maximum Replication Average
SOK MARKET PROJECT	Cash Pointss	Total Time Per Entity	Process	1,579927358	Yes	0,13096629	1,318057316	1,868040545
		VA Time Per Entity	Process	0,905248246	Yes	0,04622279	0,799824682	0,981010296
		Wait Time Per Entity	Process	0,674679112	Yes	0,11971813	0,407857652	0,973862915
	Cash Pointss.Queue	Waiting Time	Queue	0,673382911	Yes	0,1208656	0,402113178	0,962920635

ProjectName	Project RunDateTime	Replication	Name	Type	Source	Average	Minimum	Maximum	NumberObservations
SOK MARKET PROJECT	2023-12-26 16:12:10	1	Cash Pointss.Queue	Waiting Time	Queue	0,721764465	0	3,774577138	73
SOK MARKET PROJECT	2023-12-26 16:12:10	2	Cash Pointss.Queue	Waiting Time	Queue	0,525808199	0	3,167215117	89
SOK MARKET PROJECT	2023-12-26 16:12:10	3	Cash Pointss.Queue	Waiting Time	Queue	0,962920635	0	4,230656001	89
SOK MARKET PROJECT	2023-12-26 16:12:10	4	Cash Pointss.Queue	Waiting Time	Queue	0,733516642	0	2,870916207	87
SOK MARKET PROJECT	2023-12-26 16:12:10	5	Cash Pointss.Queue	Waiting Time	Queue	0,620882374	0	4,900179585	92
SOK MARKET PROJECT	2023-12-26 16:12:10	6	Cash Pointss.Queue	Waiting Time	Queue	0,878263113	0	5,147496639	87
SOK MARKET PROJECT	2023-12-26 16:12:10	7	Cash Pointss.Queue	Waiting Time	Queue	0,648511872	0	3,751469471	86
SOK MARKET PROJECT	2023-12-26 16:12:10	8	Cash Pointss.Queue	Waiting Time	Queue	0,402113178	0	3,142746474	71
SOK MARKET PROJECT	2023-12-26 16:12:10	9	Cash Pointss.Queue	Waiting Time	Queue	0,721816003	0	3,454086658	87
SOK MARKET PROJECT	2023-12-26 16:12:10	10	Cash Pointss.Queue	Waiting Time	Queue	0,518232634	0	2,172305707	80
					Total	6,7338291			
					Avr	0,673			

3. Validation and Verification:

One of the pivotal tasks in our project involves validating and verifying the model. Developers rely on the model outputs to assist managers in making informed recommendations and decisions. Every simulation model undergoes a process of verification, calibration, and validation. To grasp the concept of verification, one can simply pose questions to ensure the accuracy and reliability of the model.

*Was the construction of the model accurate within the simulation software?
*Have the input parameters of the model been correctly portrayed?

1- We ensured the precise representation of our conceptual model in the Arena software.

2- Scrutinize the output of the model for logical coherence.

3-Verify the input parameters and confirm their stability to prevent inadvertent changes.

((so now we can conclude that the verification is concerned with building the model correctly)).

3.1 The Validation and Calibration Parts:

Validation: aims to construct an accurate representation of the true model, ensuring it aligns faithfully with the real system. It enhances the model's credibility to an acceptable level, allowing developers to gain confidence in the validity of output analyses, making reliable inferences about the actual system.

Calibration: The iterative process of comparing the model to the real system and making adjustments.

And finally, we will explain how we verified the validity of our project as we will also show the calculation and all steps that we have completed.

3.2 Hypothesis Testing:

Comparing the mean value of the queue from the model with the actual mean of the queue in the real system

- We got the mean value and standard deviation from Arena software after running 10 replications. Our mean value is Y= 0.673 and the Standard deviation is SD= 0.169
- Then we calculate half width with the formula below and found H=0.121 which will be necessary in future calculations.

$$H = t_{\alpha/2,R-1} \frac{S}{\sqrt{R}}$$

- The level of significance is (α=0.05) and the sample size is (R=10)
  0.121 = 2.26 * (S/ (10^1/2))
- The null hypothesis testing: evaluating if the model and the real system are the same or not :
  H0: E(Y) = 0.722
  H1: E(Y) ≠ 0.722
  - IF H0 is not rejected, then, there is no reason to consider the model invalid.
  - IF H1 is rejected, then, the current model is rejected, and the developer should improve the model.

-Compute Test Statistics:

We made a t-test to make sure our model is valid and does not need changes.

$$|t_0| = \left| \frac{\bar{Y}_2 - \mu_0}{S / \sqrt{n}} \right|$$

t $_{0.025,9}$ = 2.26 which is also $t_{critical}$

T0 = (0.673-0.722)/ (0.169/ (10^1/2)) = 0,9176 < $t_{critical}$ which is 2.26, so don't reject null hypothesis.

-Confidence Interval Testing:

To evaluate whether the simulation and the real system are close enough. We did confidence interval testing with formula1.

$$\bar{Y} \pm t_{\alpha/2,n-1} S / \sqrt{n}$$

(0.673) ± (2.26) * 0.169/sqrt (10) = [0.552,0.794] **as our confidence interval.**

- Best case= |0.794 - 0.722| = 0.072 < 0.2

- Worst case= |0.552 - 0.722| = 0.17 < 0.2   Since worst case error is ≤ epsilon so we accept the model.

-Confidence Interval with Specified Precision:

For the calculations below as stated above standard deviation was found as SD=0.169 and epsilon=0. Also from half width formula H is calculated as H=0.121 and t-value is equal to 2.26 with R=10 replications.

Then we need to choose how many replications we must do. To do this first we have to calculate sample size R with the ***Formula1***.

$$R \geq \left(\frac{z_{\alpha/2} S_0}{\varepsilon} \right)^2$$

Formula1

R > ((-1.96*0.169)/0.2) ^2, here Epsilon was chosen as 0.2

R > 2.742 == 3 so to check how many replications are necessary our calculations should start from R=3.

Then with the ***Formula2*** we should obtain the least number of replications necessary by starting calculations from R=3 which we found above.

$$R \geq \left(\frac{t_{\alpha/2,R-1} S_0}{\varepsilon} \right)^2$$

Formula2

As S= 0.169 and epsilon is 0.2

R	[(Ta/2*S)/epsilon]^2	Comparsion
3	12,891	3<12,891
4	7,0506	4<7,0506
5	5,3883	5<5,3883
6	4,6051	6>4,6051

Table1

After calculations from ***Table1*** it can be seen that R=6 satisfied the conditions We found that at least 6 replications are needed. In our calculations we did 10 replications we do not have to change our calculations.

4. Comparison and Evaluation of Alternative System Designs (Actual Model vs. Alternative Model)

Here our purpose is to compare the system with alternative model to see if alternative model is a better solution or not. Below is the Arena output for actual model and alternative model.

Project Name	Name	Type	Source	Average Of Replication Averages	Observed=Requested	Half-Width	Minimum Replication Average	Maximum Replication Average	Overall Min Value	Overall Max Value	Avg Observations Per Replication
SOK MARKET PROJECT	Cash Pointss.Queue	Waiting Time	Queue	0,673382911	Yes	0,120865599	0,402113178	0,962920635	0	5,147496639	84,1

Project Name	Name	Type	Source	Average Of Replication Averages	Observed=Requested	Half-Width	StDev Of Replication Averages	Minimum Replication Average	Maximum Replication Average	Overall Min Value	Overall Max Value	Avg Observations Per Replication
Alternative Model	Cash Pointss.Queue	Waiting Time	Queue	0,030071645	Yes	0,010109262	0,014131773	0,01165591	0,050770607	0	1,211735593	84,5

-Degrees of Freedom Calculation:

Because variances for alternative model and actual model are different to find the confidence interval first, we have to find degrees of freedom value which can be found by ***Formula4***.

$$\upsilon = \frac{\left(S_1^2 / R_1 + S_2^2 / R_2\right)^2}{\left[\left(S_1^2 / R_1\right)^2 / (R_1 - 1)\right] + \left[\left(S_2^2 / R_2\right)^2 / (R_2 - 1)\right]}$$

Formula4

$S_1 = 0.14718$ and $S_2 = 0.0001997$ also we have 10 replications for both models so $R_1 = R_2 = 10$. When we did the calculations with these numbers, we found the degrees of freedom value as 9.1659. it should be rounded up so **v=10**.

-Standard Error Calculation:

After that standard error should also be found. To find the standard error we have used the ***Formula5***.

$$s.e.\left(\bar{Y}_{.1} - \bar{Y}_{.2}\right) = \sqrt{\frac{S_1^2}{R_1} + \frac{S_2^2}{R_2}}$$

Formula5

As stated $R_1 = R_2 = 10$ and after calculations standard error is found as **s.e (Y1-Y2) = 0.0467**

-Confidence Interval Calculation:

After finding degrees of freedom value and standard error value, confidence interval can be calcuted by ***Formula6***.

$$\bar{Y}_{.1} - \bar{Y}_{.2} \pm t_{\alpha/2,\upsilon} s.e.(\bar{Y}_{.1} - \bar{Y}_{.2})$$

$$Formula6$$

Confidence Interval = $0.6433 \pm t_{0.025,10} * 0.0467$ = **(0.5390,0.7457) = C.I**

-Comparison of Ɵ1 and Ɵ2:

After finding the confidence interval we looked at Θ_1 and Θ_2 values.

$$\theta_1 = E(Y_{r1}), \ r = 1, \ldots, R_1; \qquad \theta_2 = E(Y_{r2}), \ r = 1, \ldots, R_2$$

Values for Θ_1 and Θ_2 are: **Θ_1 = 0.67338 Θ_2 = 0.03007**

After that for comparison because confidence interval is (0.5390,0.7457) which is totally to the right of 0, strong evidence for the hypothesis that $\theta_1 - \theta_2 > 0$ ($\theta_1 > \theta_2$). To see if this condition is satisfied we calculated the difference of $\theta_1 - \theta_2$ and found it as 0.6433 which is bigger than 0. So $\theta_1 - \theta_2 = 0.6433 > 0$ so the condition is satisfied therefore it can be accepted.

After these calculations we also checked one more condition which is if $\theta_1 - \theta_2$ is bigger than standard error value or not. As stated above standard error is equal to 0.0467 and $\theta_1 - \theta_2$ is equal to 0.6433. Because $\theta_1 - \theta_2$=0.6433 > s.e (Y1-Y2) = 0.0467 the condition is satisfied, and model can be accepted.

5. Cost Analysis

5.1 Cost Analysis Assumptions

1. The cost of a new cash register is (initial investment) 2,500 TL for a simple credit card reader (POS device) and 17,000 TL for a cash register.

2. Long-term employment of a new worker is calculated by using the minimum wage in Türkiye, which is 17,002.0 TL. For our convenience, we rounded that down to 17,000 TL. The worker is assumed to work for a total of 84 hours each week.

3. Average ordering time for a customer is assumed to be equal to the mean waiting time of 43.34 seconds for convenience.

4. Since we had 86 total customers for two days, the number roughly comes out to be 43 each day.

5. The profit earned from each customer is 10 liras.

5.2 Cost Analysis Computations

Calculating the total number of customers served extra from the additional cash register:

$$\mathbf{1}\ hours = \mathbf{3{,}600}\ seconds$$

$$\mathbf{3{,}600} / \mathbf{43.34} = \mathbf{83.06} \sim \mathbf{83}\ customers$$

$$\mathbf{83} - \mathbf{43} = \mathbf{40}\ extra\ customers\ per\ day$$

$$\mathbf{40}\ customers \times \mathbf{10}\ TL\ profit = \mathbf{400}\ TL\ extra\ profit\ per\ 1\ \text{hours}$$

Let the initial investment of 17,000 + 2,500 = 19,500 be considered a monthly expense. Our location of sok is open for 12 hours, every day of the week. That makes:

$$\mathbf{12}\ hours \times \mathbf{7}\ days\ per\ week \times \mathbf{4}\ weeks\ per\ month = \mathbf{336}\ hours\ per\ month$$

$$\mathbf{19{,}500} / \mathbf{336} = \mathbf{58.03}\ TL\ initialization\ expense\ per\ hour$$

For one hours:

$$\mathbf{58.03}\ TL \times \mathbf{1}\ hours = \mathbf{58.03}\ TL\ per\ observation\ period\ of\ 1\ hour$$

Calculating the employment expense, we get:

$$\mathbf{17{,}000}\ TL / \mathbf{12}\ hours \times \mathbf{7}\ \text{day} \times \mathbf{4}\ weeks = \mathbf{50.59}\ TL\ employment\ expense\ per\ hour$$

$$\mathbf{400}\ TL / \mathbf{58.03}\ TL = \mathbf{6.89}$$

If we disregard the worker cost, the hardware pays itself out **6.89** times in a month. If we were to do the same calculations for the initialization for a 2-month period, we get:

$$\mathbf{12}\ hours \times \mathbf{7}\ days \times \mathbf{4}\ weeks \times \mathbf{2}\ months = \mathbf{672}\ hours\ per\ month$$

$$\mathbf{19{,}500} / \mathbf{672} = \mathbf{29.01}\ TL\ initialization\ expense\ per\ hour$$

$$\mathbf{29.01}\ TL \times \mathbf{1}\ hours = \mathbf{29.01}\ TL\ per\ observation\ period\ of\ 1\ hour\text{s}$$

Total expense then comes out to be:

$$\mathbf{29.01}\ TL + \mathbf{336}\ TL = \mathbf{365.01}\ TL\ total\ expense\ per\ 1\ hours$$

The cost of initialization and employment turn into pure profit in less than 2 months since

$$\mathbf{365.01}\ TL < \mathbf{400}\ TL$$

5.3 Outcome of Cost Analysis

We do not even think that a two-month investment is a long-term one for a mega-corporation in Turkey like Şok. The investment appears reasonable when considering the minimal minimum standards of hiring and hardware purchases, even though our model proves to be insufficient. A new cash register might have been a smart idea if it were known with certainty that the waiting time would be removed (that is, if the model was suitable and acceptable).

6. Conclusion

In this project, we examined the situation at "our university," and based on our observations (Sok), we collect data. Our goal was to identify areas for improvement in models, systems, or business operations and outline a proposed course of action for addressing the identified issues. Analysis of the collected data revealed a significant queue at Sok between 17:00 and 18:00, attributed to students completing their classes at 16:30 and heading to Sok thereafter.

In response to this issue, we aimed to develop a more effective alternative model. Our plan involved reducing the queue time by introducing a new registration process within the alternative model. However, we encountered challenges in creating the necessary alternative model because the service queue time was already lower than expected in our initial model.