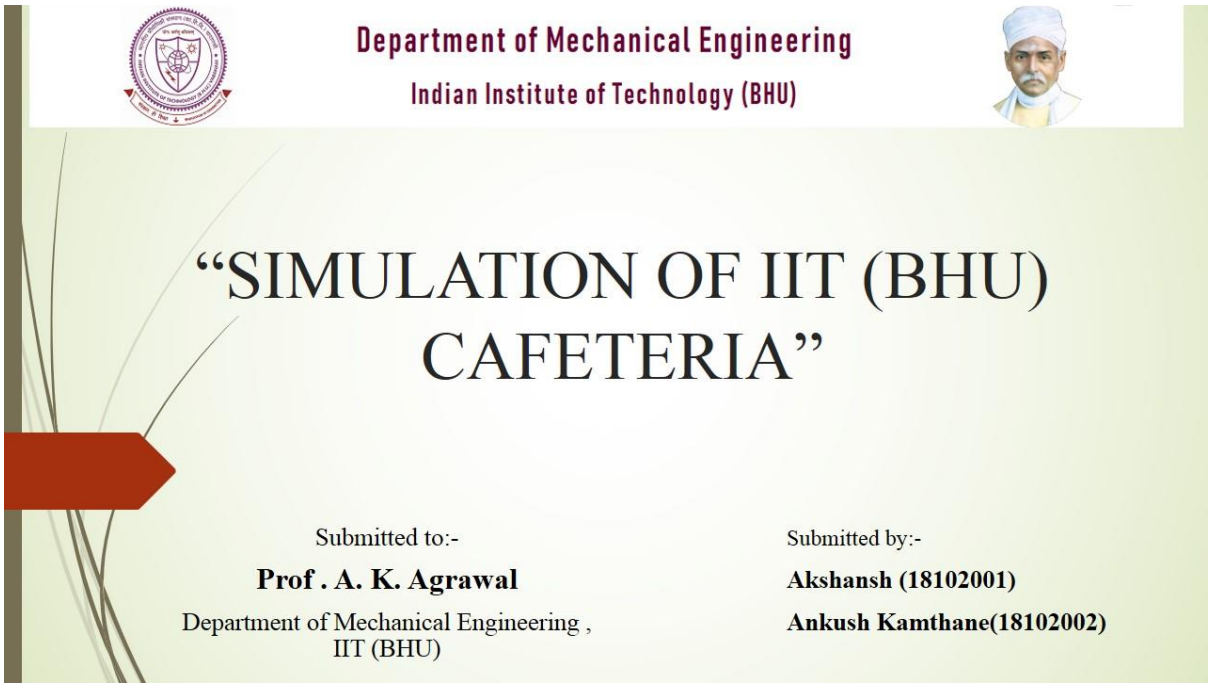
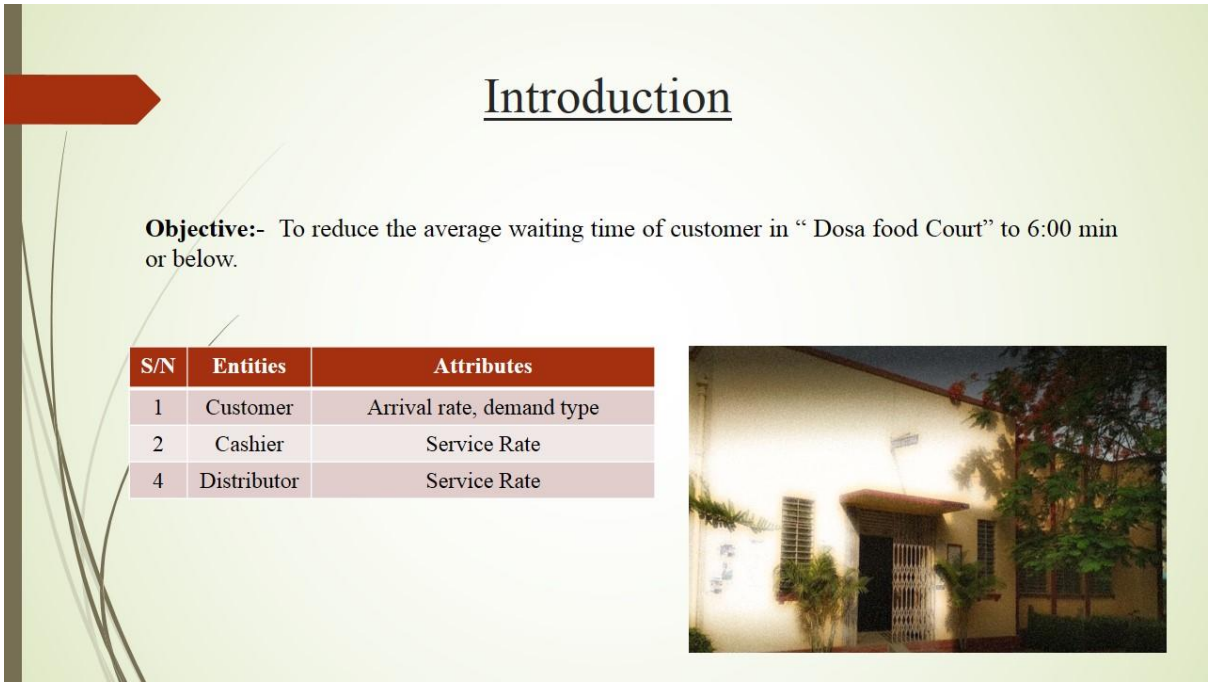


Acknowledgements

We would like to thank our Prof. A.K. AGRAWAL, for the patient guidance, encouragement and advice he has provided throughout this project. we have been extremely lucky to have a guide who cared so much about our work, and who responded to our questions and queries so promptly. I would also like to thank all the members of staff at IIT-BHU cafeteria who helped us in our project. We would also like to thank our fellow classmates and TA's Mr. Anurag and Mr. Ankit for there kind feedback.

ABSTRACT:

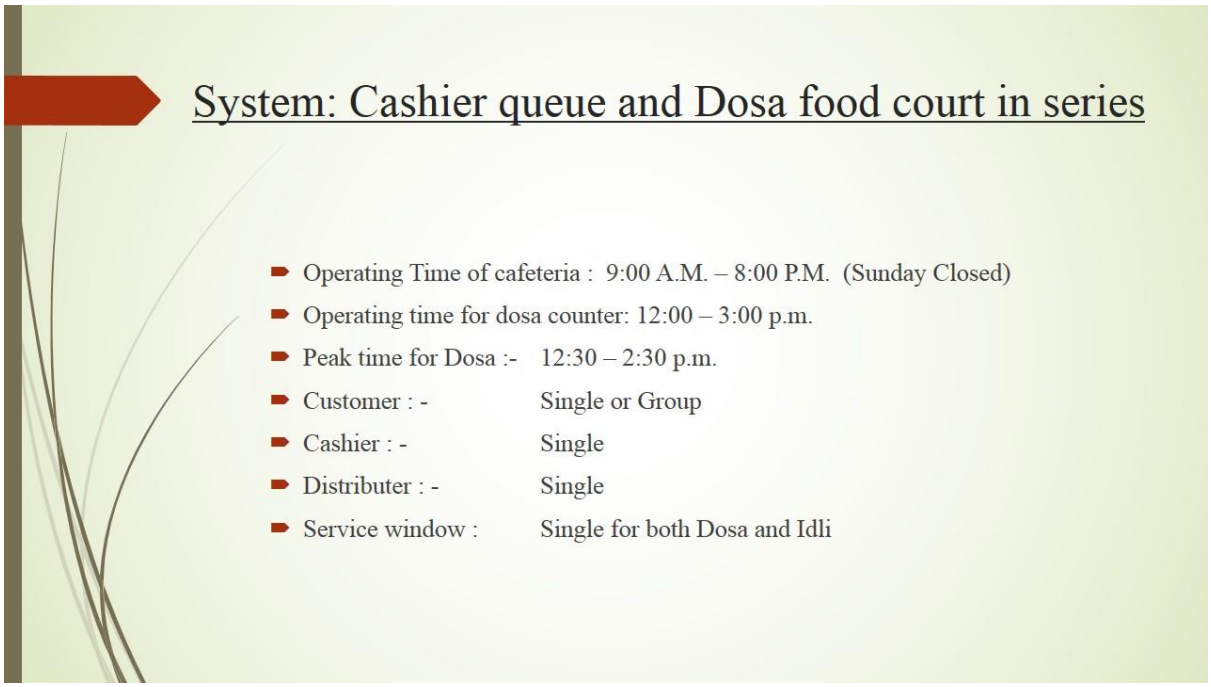
In this simulation of IIT-BHU cafeteria, cash counter and dosa counter (counter no. 2) queue was joined in series to be analysed as a system. System was simulated at peak hours. Customer arrival was generated as soon as the customer joins the cash counter queue and the inter-arrival time was noted down. Once the customer reaches the cash window, its service time and request time was noted to plot the frequency distribution of inter-arrival and service time of customer and to also find out the proportion of people ordering dosa. Then service time of customer at dosa queue were noted down to plot frequency distribution. The average waiting time in dosa queue was noted down manually for model validation and testing. Once the simulation model was constructed and simulation was run at peak hours, for a no. of replications, the model is validated. Results were coming out to be positive for assumed significance level at 5% and further suggestions were made to reduce that average waiting time. A virtual model was advised by introducing another dosa counter in parallel to the running one with identical characteristics and avg. waiting time is reduced to 2-3 minutes as desired.



INTR0DUCTION:

Our objective was to reduce the average waiting time of customer in dosa food court to less than its critical time. Critical time is the time customers are willing to wait without feeling exhausted in the system. It purely depends on customer so we took a survey of around 15 people and averaged it out to 6 minutes. **Entities** are discrete items of interest in a discrete-event **simulation** and attributes are there characteristics. In our system, customer, cashier at cash counter and distributor at dosa counter are entities and there attributes are inter-arrival time and service time.

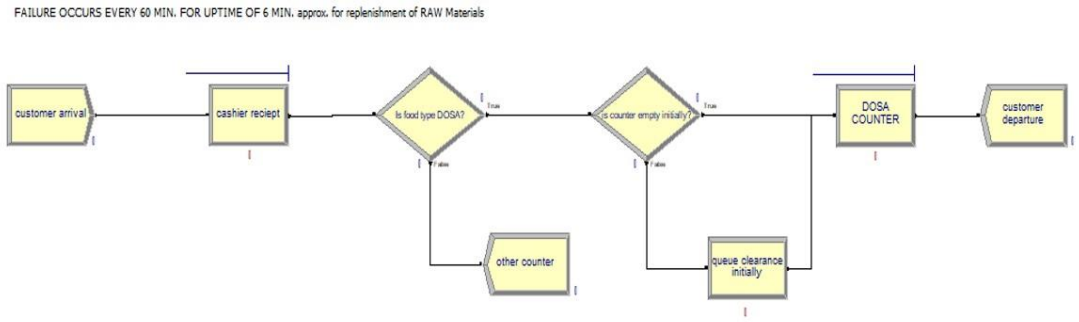
Our system characteristics are:



Customer arrives as either group or single but it was observed that only one person out of the group joins the cash counter for placing the order so arrival event occurs once the customer joins the queue and multiple people in group are considered as single arrival event as well.

*the last assumption was made to imply simplicity at counter window. As people arriving for both dosa and idli are served at the same counter but the idli demand does not hinder the customer waiting for dosa at the counter window.

SIMULATION OF IIT- CAFETERIA



Resource - Basic Process

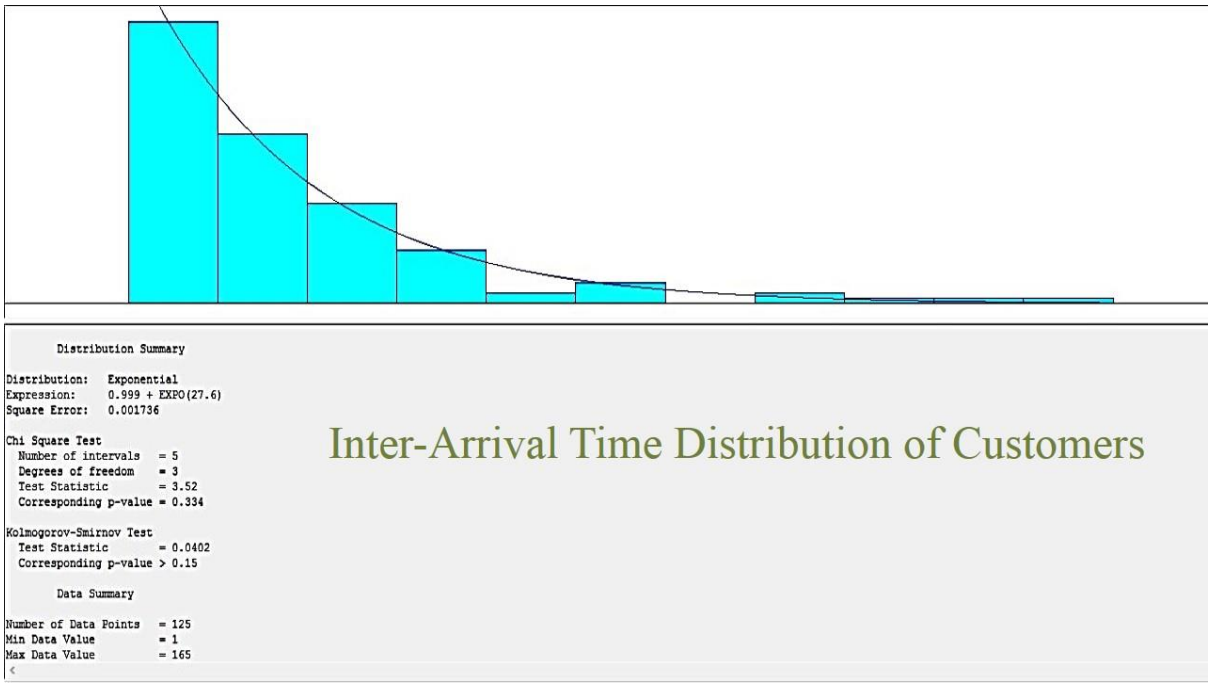
	Name	Type	Capacity	Busy / Hour	Idle / Hour	Per Use	StateSet Name	Failures	Report Statistics
1	cashier	Fixed Capacity	1	0.0	0.0	0.0		0 rows	☑
2	distributor1	Fixed Capacity	1	0.0	0.0	0.0		1 rows	☑

ARENA SIMULATION MODEL:

The **ARENA** discrete event system simulation model is used for modelling our system. The customer arrival module is added and is joined to cashier counter process module where cashier as a resource is added. Then a check module based on 2-way by proportion is selected and demand for dosa is separated from demand of other food items. Customer with dosa demand type are further sent to join the dosa counter. A check module is added before the DOSA COUNTER to simplify **INITIALISATION CONDITION** i.e. when we begin the simulation, there will always be few customers already standing at dosa queue as counter opens at 12:00p.m. and simulation begins at 12:30 p.m. so the first arrival has to wait for some time initially for queue clearance and the the system will run steadily. After the person is served at dosa counter, customer leaves the system so a dispose module is added in the end.

*it was observed that the distributor at dosa counter has to refill the raw materials every one hour on an average and it takes about 6 minutes to replenish it so a failure is added to Dosa Counter for every 60 minutes with a down time for 6 minutes.

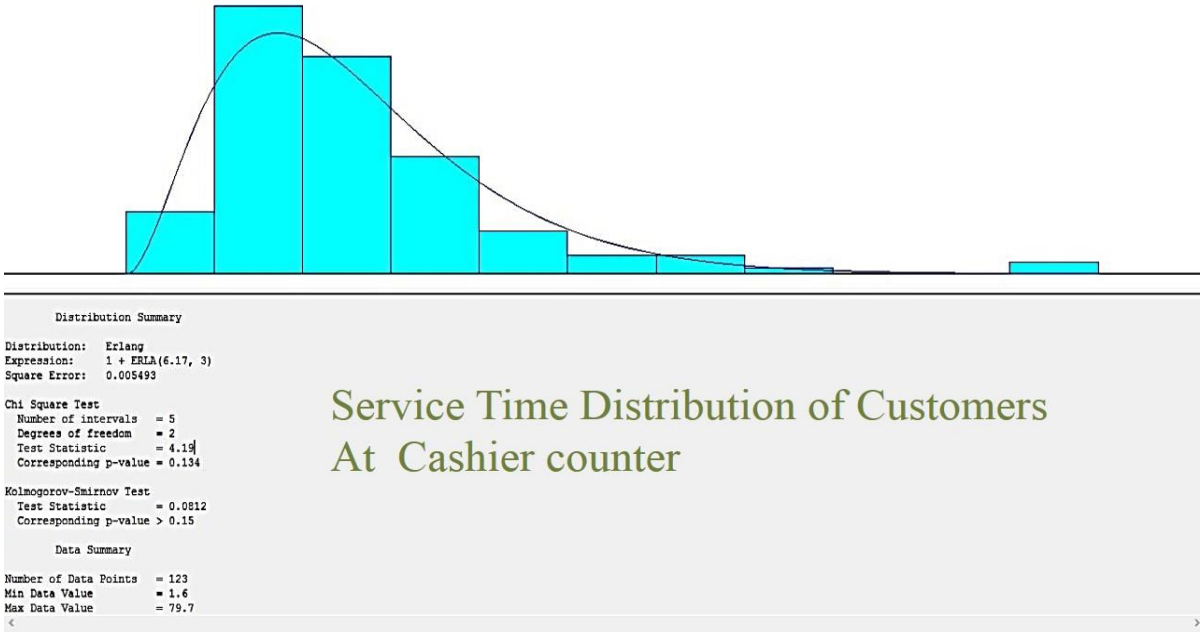
INTER-ARRIVAL TIME DISTRIBUTION AT CASH COUNTER:



INTER-ARRIVAL Time of customers is measured using a stop watch with least count of 1 mill second and precision upto one decimal point in seconds. The readings were started at 12:30 p.m. and arrival time of each customer after that were noted down from which inter-arrival time was sorted out. Around 125 observations were noted on a single day and were plotted using arena input analyser. The distribution was coming out to be exponential with mean 27.4 seconds.

Similarly, service time at cash counter is measured using same criterion and it was coming out to be ERLANG distribution with alpha 6.17 and beta as 3. Erlang distribution is a sum of multiple exponential distribution. The same procedure is followed for DOSA counter as well.

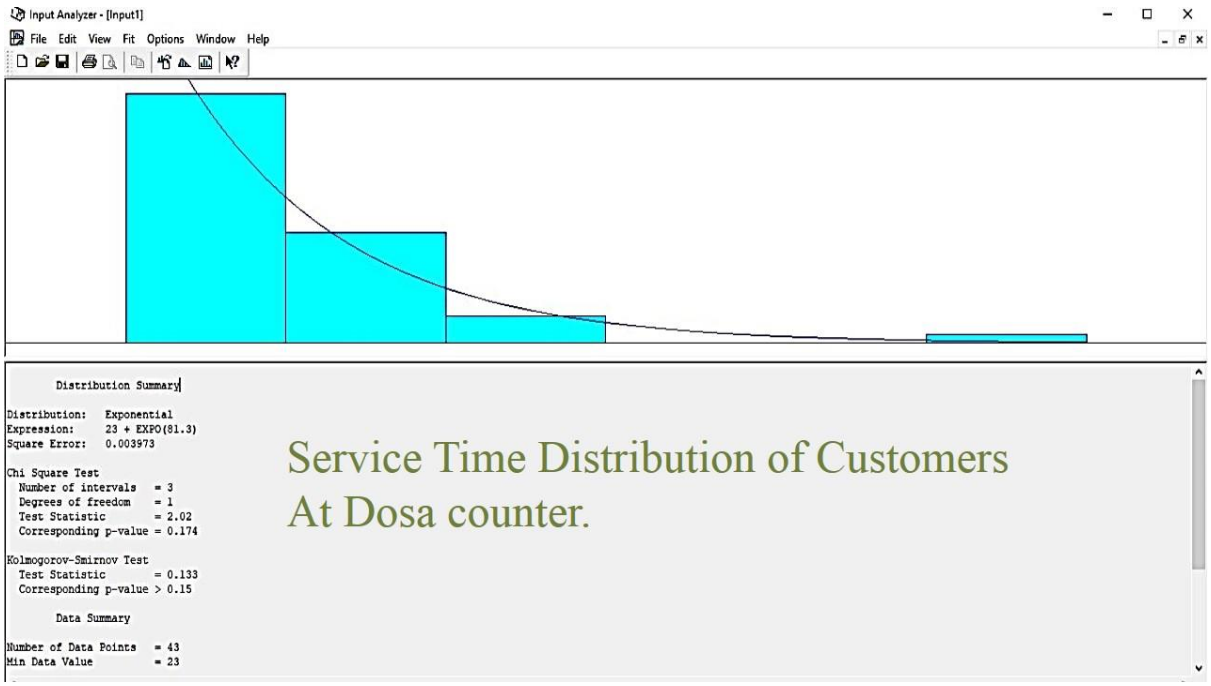
SERVICE TIME DISTRIBUTION AT CASH COUNTER:



PROPORTION OF CUSTOMER WITH DOSA DEMAND:

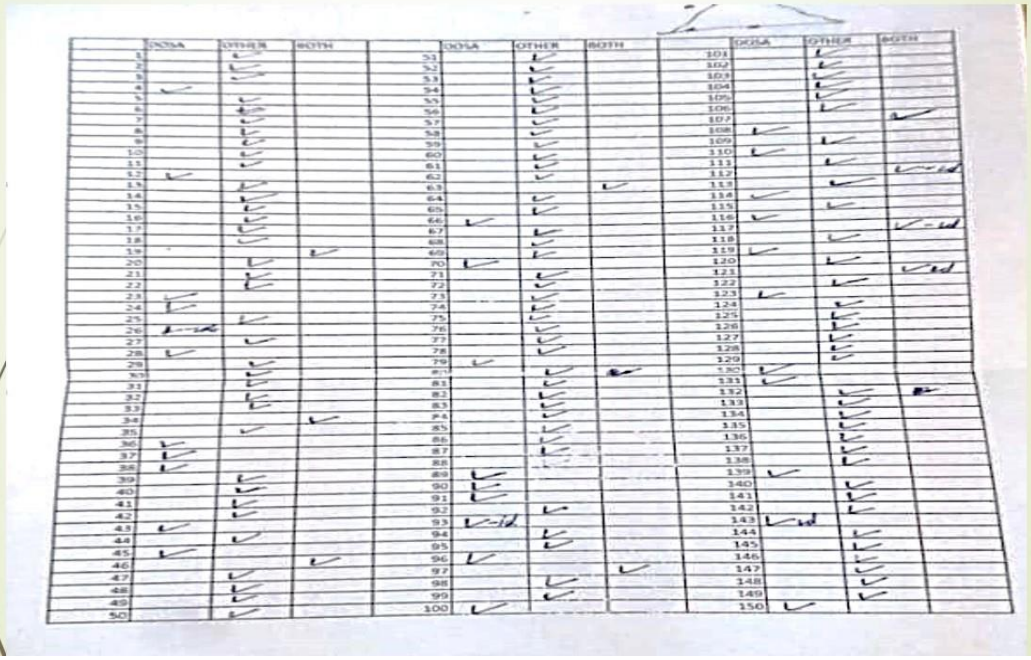
To find the proportion of people asking for dosa, we made a check list with three columns i.e. customer asking for dosa, customer for other food items, and customer with both kind of demand. We took 150 observations and found out that 26.67% of people are asking for dosa type food and very few are asking for both dosa and other types. It was observed that people asking for both generally ask for tea/coffee or other beverage which usually takes lesser time to served hence even most of them prefer to visit dosa queue first.

To measure the average waiting time of customers waiting in dosa queue, we made slips with " queue joining time " and " time to reach window " and distributed them to customers with respective time of joining written manually and similarly, slips were collected as soon as customer reaches the service window and the time was noted on those slips manually. The time difference gives the waiting time of customer and was averaged out for output analysis.

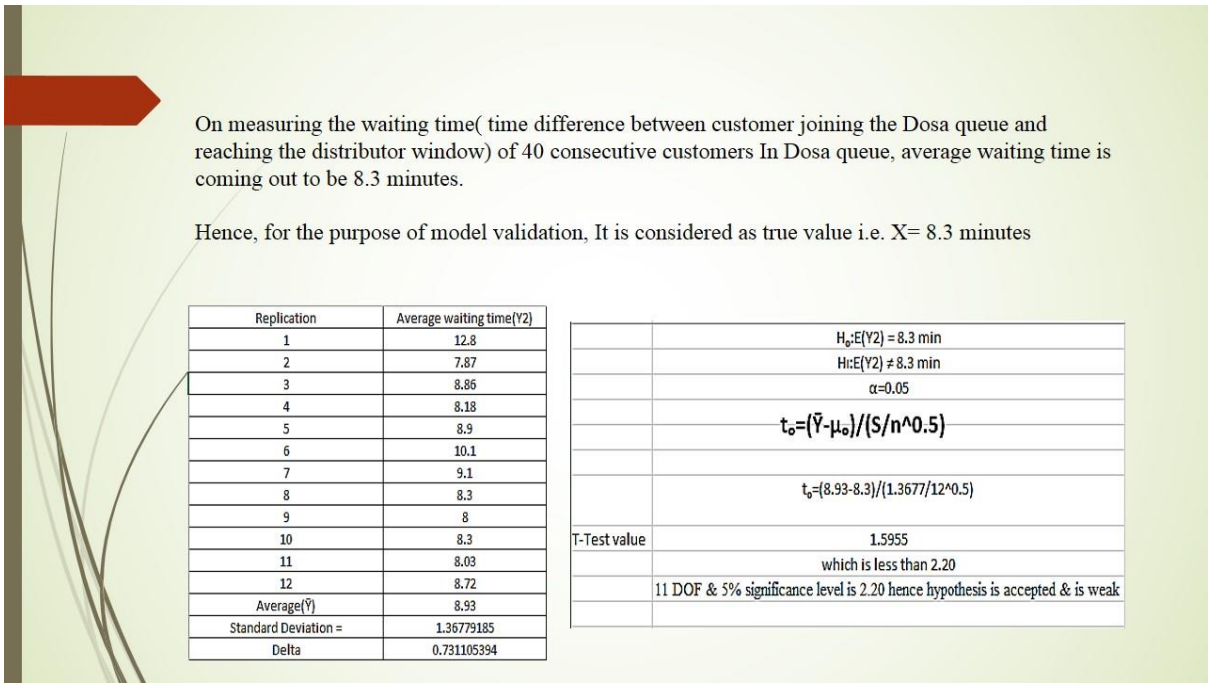


Service Time Distribution of Customers At Dosa counter.

Probability of customer asking for Dosa is coming out to be 26.67%



After data was obtained, simulation was run for 12 replications initially and average time in dosa queue was noted down for validation. Alpha and B testing was done and required number of replications were evaluated from OC-Characteristic curve for Beta testing. The required replications (30) were found for appropriate significance level and both alpha and beta tests were performed again for validation of model.



On measuring the waiting time(time difference between customer joining the Dosa queue and reaching the distributor window) of 40 consecutive customers In Dosa queue, average waiting time is coming out to be 8.3 minutes.

Hence, for the purpose of model validation, It is considered as true value i.e. X= 8.3 minutes

Replication	Average waiting time(Y2)
1	12.8
2	7.87
3	8.86
4	8.18
5	8.9
6	10.1
7	9.1
8	8.3
9	8
10	8.3
11	8.03
12	8.72
Average($\bar{Y}$)	8.93
Standard Deviation =	1.36779185
Delta	0.731105394

	H_o:E(Y2) = 8.3 min
	Hi:E(Y2) ≠ 8.3 min
	α=0.05
	$t_o=(\bar{Y}-\mu_o)/(S/n^{0.5})$
	t_o=(8.93-8.3)/(1.3677/12^0.5)
T-Test value	1.5955
	which is less than 2.20
	11 DOF & 5% significance level is 2.20 hence hypothesis is accepted & is weak

Once the model is validated, we need to find the confidence intervals at 95% confidence level and 30 replications. The observed value lies in between the confidence interval. Then to reduce the average waiting time below 6 minutes, another dosa counter with identical attributes is added in parallel with present counter and simulation was performed. The average waiting time was coming out to be 2 minutes which was far better than expected.

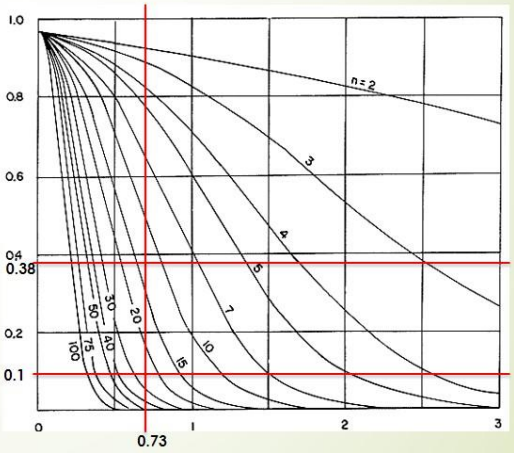
β-Testing

$$\delta = \frac{|E(Y_2) - \mu_o|}{\sigma} = \frac{1}{1.3677} = 0.731$$

We would like to reject H_o with probability at least 0.9 if the true mean delay of the model differed from the average delay in the system by 1 min.

for δ = 0.731 and n=12 the value of probability of accepting H_o even when H_1 is true is coming out to be 0.38, which is not less than 0.1 hence our hypothesis fails B-test at 12 replications.

From the graph itself, to have a value less than 0.1, we need nearly 30 replications.



Replication	Average waiting time
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11	8.03
12	8.72
13	8.5
14	8.08
15	7.87
16	7.71
17	7.59
18	7.56
19	7.75
20	7.51
21	7.49
22	7.26
23	7.13
24	7.01
25	7.1
26	7.07
27	6.95
28	6.87
29	6.84
30	6.75
Average	8.006666667
Std Dev	1.196051934

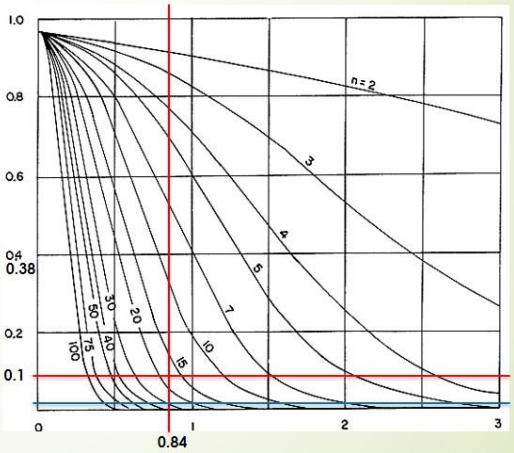
	H_o:E(Y2) = 8.3 min
	H1:E(Y2) ≠ 8.3 min
	α=0.05
	$t_o=(\bar{Y}-\mu_o)/(S/n^{0.5})$
	t_o=(8.93-8.3)/(1.196/30^0.5)
T-Test value	-1.3433
	which is less than 2.04
	29 DOF & 5% significance level is 2.04 hence hypothesis is accepted & is weak

β-Testing

$$\delta = \frac{|E(Y_2) - \mu_o|}{\sigma} = \frac{1}{1.196} = 0.836$$

We would like to reject H_o with probability at least 0.9 if the true mean delay of the model differed from the average delay in the system by 1 min.

for δ = 0.836 and n=30 the value of probability of accepting H_o even when H_1 is true is coming out to be less than 0.1 hence our hypothesis fails B-test at 30 replications is true.

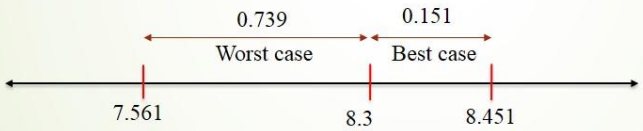


CONFIDENCE INTERVAL BASED ON 30 REPLICATIONS

$$\bar{y} \pm t_{0.025,29} s/\sqrt{n}$$

$$8.006 \pm 2.04 * 1.196/\sqrt{30}$$

Interval : $\{7.561, 8.451\}$

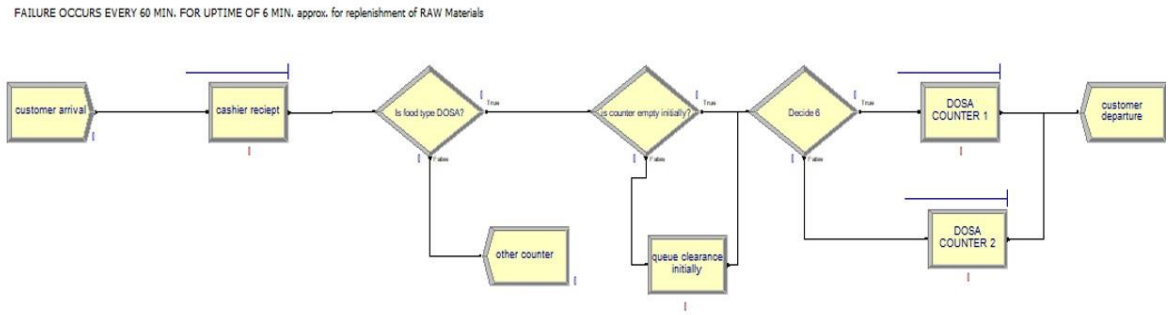


As in both worst case and best case time is coming out to be less than 1 minute,
Hence our simulation model is a valid model.

Suggestions for the reduction of average waiting time to 6 minutes.

1. Peak hour demand of dosa increases generally when the "dal roti sabji" is sold out, which usually occurs around 1:00 PM. Hence by managing the quantity of "dal roti sabji" we can decrease the demand of dosa and thus the average waiting time per customers.
2. By adding a new dosa cook in parallel with the existing one can increase the service rate and thus reduce the average waiting time.
3. By increasing the number of dosa from two to three per batch can increase the service rate and hence can reduce the average waiting time.

SIMULATION OF IIT- CAFETERIA



Resource - Basic Process

	Name	Type	Capacity	Busy / Hour	Idle / Hour	Per Use	StateSet Name	Failures	Report Statistics
1	cashier	Fixed Capacity	1	0.0	0.0	0.0		0 rows	☑
2	distributor1	Fixed Capacity	1	0.0	0.0	0.0		1 rows	☑
3	cook2	Fixed Capacity	1	0.0	0.0	0.0		1 rows	☑

1:27:11AM **Category Overview** April 19, 2019

Values Across All Replications

Unnamed Project

Replications: 10 Time Units: Minutes

Queue

Time

Waiting Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
cashier reciept.Queue	0.4149	0.12	0.1831	0.7219	0.00	3.5564
DOSA COUNTER 1.Queue	1.4163	0.25	0.9482	2.0142	0.00	13.9654
DOSA COUNTER 2.Queue	1.4653	0.54	0.3734	2.4418	0.00	8.7427

Other

Number Waiting	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
cashier reciept.Queue	0.8798	0.27	0.3326	1.4377	0.00	12.0000
DOSA COUNTER 1.Queue	0.5485	0.10	0.3505	0.7548	0.00	5.0000
DOSA COUNTER 2.Queue	0.2542	0.09	0.06435906	0.4419	0.00	4.0000

RESULTS

Initially the average waiting time of customers in Dosa queue was coming out to be 8.3 minutes. Virtually, after introducing another Dosa counter with similar service time distribution in parallel to initial one, we can reduce the average waiting time to 2 minutes.