

# **IE 3081 MODELLING AND DISCRETE SIMULATION – PROJECT**

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## **PART A:**

### **SYSTEM COMPONENTS**

#### ENTITIES and ATTRIBUTES:

- Student
- Academician
- Classic Dining Hall Food Service Points for Students (Speed, Probability)
  - Classic Service Left-side (Speed: slow by classic service)
  - Classic Service Right-side (Speed: fast by classic service)
- Vegetarian, vegan and Gluten-free Dining Hall Food Service Point for Students (Speed, Probability)
- Dining Hall Service Point for Academicians (Speed, Probability)
- Dining Area
- ATM Machine (Probability)

#### ACTIVITIES:

- Student may go to classic dining hall food service points.
- Student may go to vegetarian and gluten-free dining hall food service point.
- Student may go to ATM.
- Academicians go to dining hall service point.
- After the dining hall food service, everyone goes to the dining area.
- After loading money from the ATM, everyone goes to one of the dining hall food services.

#### EVENTS:

- Students or academicians arrival to the dining hall.
- Students may or may not pass dining hall service points according to their balance.

- Serve food.

#### STATES:

- Busy
- Idle

#### DELAYS:

- Students wait in one of the food service queue.
- Students wait in the ATM queue.
- Students wait in the dining area.
- Academicians wait in the food service queue.

### RELATIONS BETWEEN SYSTEM COMPONENTS

- According to the possibilities, the academician or student arrive the dining hall.
- The student goes to ATM or classic or vegetarian, gluten-free food service depending on the possibilities. If there is a queue, they wait in line.
- If the student went to the ATM, he/she enters the food service queue after the ATM.
- Students leaving the food service points stand in line in case of a queue at the dining area.
- The academician goes directly to the academician food service point. If there is a queue, they wait in line.
- Academicians who leave the food service point go to the dining hall. If there is a queue, they wait.

### PERFORMANCE METRICS

- Number of all people that use dining hall
- Number of students
- Number of academicians
- Number of students who use vegetarian and gluten-free dining hall service point

- Number of students who use classical dining hall service point that has more speed
- Number of students who use classical dining hall service point
- Number of students who use ATM
- Number of total dining hall service
- The total time students waiting in the queue
- The total time academicians waiting in the queue
- The average time students or academicians waiting in the queue
- The average service time of each dining hall service points and ATM and dining area
- Idle time of each dining hall service points and ATM and dining area

## **SYSTEM DESIGN 1**

- 1 waiting queue for dining hall service for academicians.
- 3 waiting queue for dining hall service for students.
  - 1 waiting queue for dining hall service for students that have a tolerance to vegan or gluten
  - 1 waiting queue for classical dining hall service that has faster.
  - 1 waiting queue for classical dining hall service that has more slowly.
- 1 waiting queue for ATM for students.
- 1 waiting queue for dining area for academicians and students.
- 1 dining hall service for academicians
- 3 dining hall service for students
  - 1 dining hall service for students that have a tolerance to vegan or gluten
  - 1 classical dining hall service that has faster.
  - 1 classical dining hall service that has more slowly.
- 1 dining area service for academicians and students.

## INPUT VARIABLES

Person Arrival Time	
1.0	0.15
2.0	0.25
3.0	0.35
4.0	0.25

Academician Distrubution	
1.0	0.4
2.0	0.3
3.0	0.3

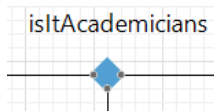
VGDistrubution	
1.0	0.33
2.0	0.33
3.0	0.17
4.0	0.17

ClassicalDistrubutionFast	
1.0	0.17
2.0	0.32
3.0	0.21
4.0	0.3

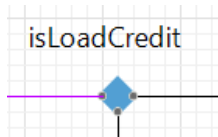
ClassicalDistrubutionSlow	
1.0	0.25
2.0	0.3
3.0	0.25
4.0	0.2

Dining Area Distrubution	
1.0	0.32
2.0	0.36
3.0	0.2
4.0	0.12

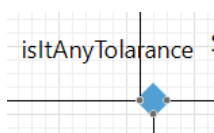
ATMDistrubution	
1.0	0.22
2.0	0.16
3.0	0.41
4.0	0.21



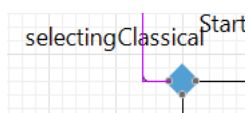
Condition : *randomTrue( 0.1 )*



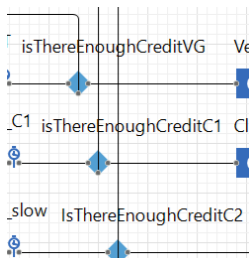
Condition : *randomTrue( 0.2 )*



Probability : 0.1

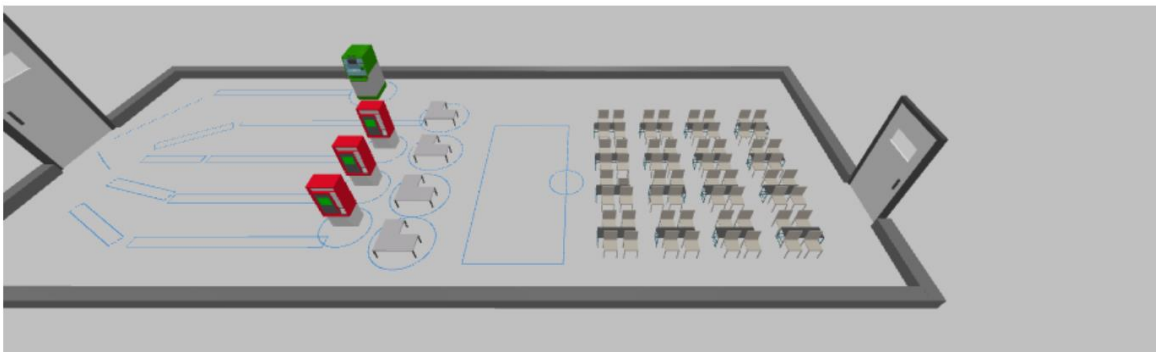
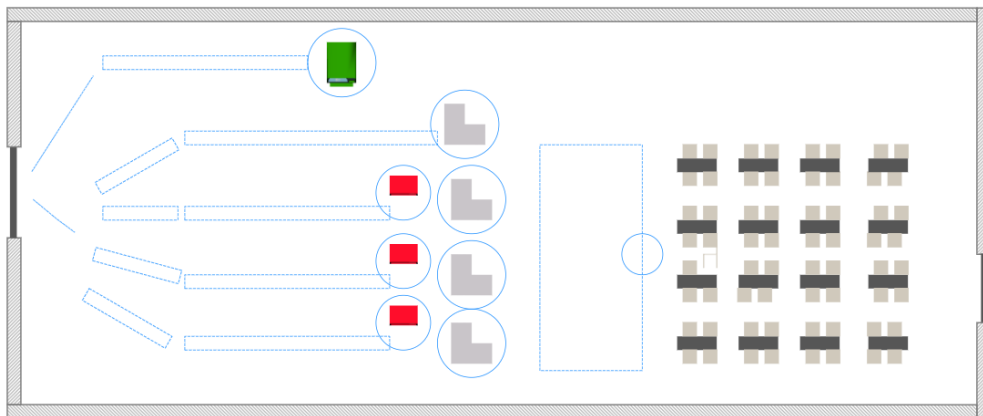
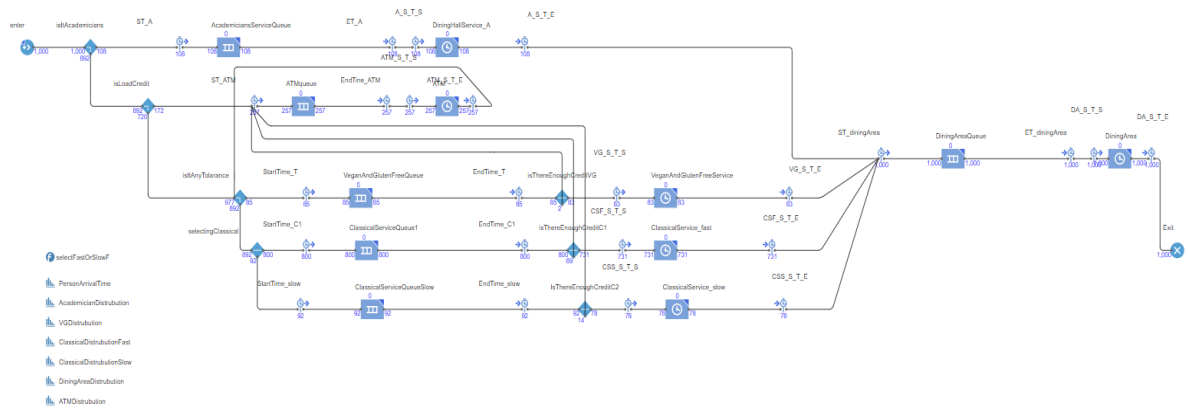


Condition: *selectFastOrSlowF();*



Probability of each of them: 0.9

## 2D And 3D View of The Model



## ALTERNATIVE SYSTEM DESIGN

In this simulation, we will see the number of service points how affect the system. So for the analyze, in alternative scenario, we will decrease the faster classical service point that servicing to students. Also some of the distributions are different from the first system.

- 1 waiting queue for dining hall service for academicians.
- 3 waiting queue for dining hall service for students.
  - 1 waiting queue for dining hall service for students that have a tolerance to vegan or gluten
  - 1 waiting queue for classical dining hall service
- 1 waiting queue for ATM for students.
- 1 waiting queue for dining area for academicians and students.
- 1 dining hall service for academicians
- 3 dining hall service for students
  - 1 dining hall service for students that have a tolerance to vegan or gluten
  - 1 classical dining hall service
- 1 dining area service for academicians and students.

## INPUT VARIABLES

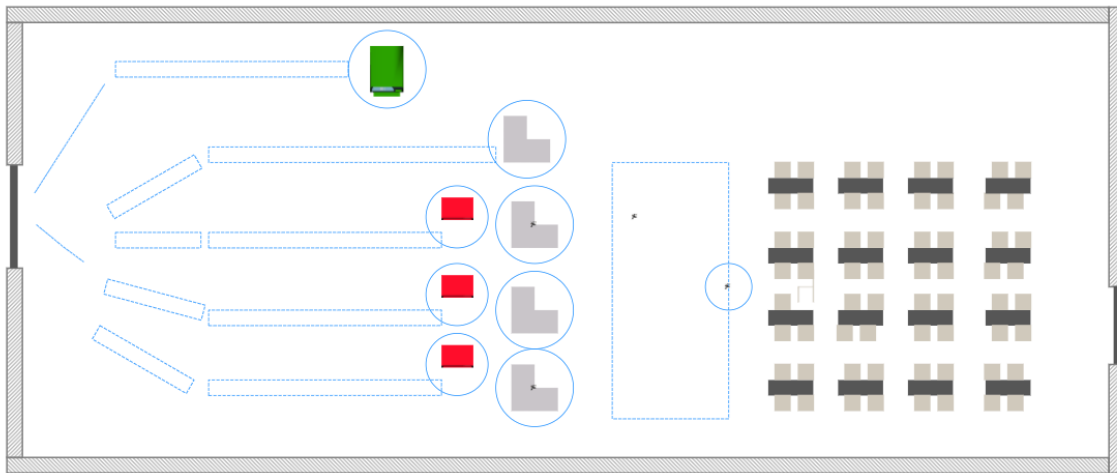
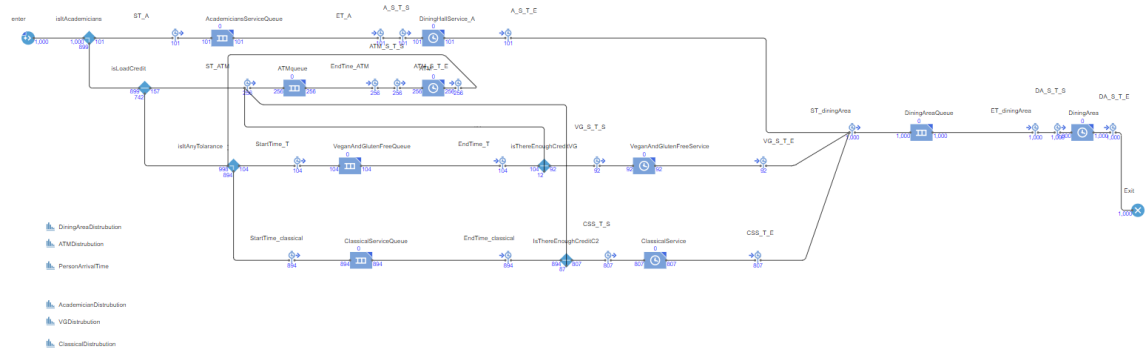
Person Arrival Time		ATMDistrubution		Dining Area Distrubution		ATMDistrubution	
1.0	0.15	1.0	0.22	1.0	0.32	1.0	0.22
2.0	0.25	2.0	0.16	2.0	0.36	2.0	0.16
3.0	0.35	3.0	0.41	3.0	0.2	3.0	0.41
4.0	0.25	4.0	0.21	4.0	0.12	4.0	0.21

Academicians Distrubution		VGD Distrubution		Classical Service Distrubution	
1.0	0.25	1.0	0.22	1.0	0.15
2.0	0.4	2.0	0.38	2.0	0.25
3.0	0.35	3.0	0.18	3.0	0.41
		4.0	0.22	4.0	0.19

- Probability are the same with system design 1.

## 2D And 3D View of The Model



## PART B:

- Estimate the mean values for the output (performance) parameters you defined above. You have to run (replicate) the simulation several times with different seed values. Estimates should be the mean of all runs (replications).

Performance Metrics / Seed value	1	4	12	17	25	Response
Number of all people that use dining hall	1000	1000	1000	1000	1000	1000
Number of students	892	891	911	877	918	897,8
Number of academicians	108	109	89	123	82	102,2
Number of students who use vegetarian and gluten-free dining hall service point	83	86	85	99	84	87,4
Number of students who use classical dining hall service point that has more speed	731	711	738	688	729	719,4
Number of students who use classical dining hall service point slow	92	94	88	90	105	93,8
Number of students who use ATM	257	164	267	267	269	244,8
Number of total dining hall service	6	6	6	6	6	6
The total time students waiting in the queue without dining area	575	608	655	533	634	601
The total time academicians waiting in the queue without dining area	0	2	1	4	0	1,4
The average time students waiting in the queue	0,64	0,68	0,718	0,607	0,69	0,667
The average time academicians waiting in the queue	0	0,018	0,011	0,008	0	0,0074
Total time academicians and student waiting in the queue with dining area	2158	2630	2157	2710	2168	2364,6
Average academicians and student waiting in the queue with dining area	2,15	2,63	2,15	2,71	2,16	2,36
The average service time of dining hall service point for academicians	2,056	2,028	1,955	1,85	1,939	1,9656
The average service time of dining hall service point for ATM	2,607	2,541	2,7	2,64	2,766	2,6508
The average service time of dining hall service point for VeganAndGlutenFreeService	2,181	2,302	2,388	2,172	2,143	2,2372
The average service time of dining hall service point for ClassicalService_fast	3	2,626	2,656	2,622	2,626	2,706
The average service time of dining hall service point for ClassicalService_slow	2,385	2,277	2,443	2,444	2,448	2,3994
The average service time of dining hall service point for DiningArea	2,15	2,139	2,111	2,178	2,381	2,1918
Idle time of dining hall service point for academicians	2593	2875	2801	2656	2583	2701,6
Idle time of dining hall service point for ATM	2145	2410	2254	2173	1988	2194
Idle time of dining hall service point for VeganAndGlutenFreeService	2634	2898	2772	2663	2562	2705,8
Idle time of dining hall service point for ClassicalService_fast	862	1232	1015	1074	828	1002,2
Idle time of dining hall service point for ClassicalService_slow	2629	2882	2760	2658	2492	2684,2
Idle time of dining hall service point for DiningArea	665	957	864	700	637	764,6

Figure 1: SYSTEM 1 for 1<sup>st</sup> question



Performance Metrics / Seed value	1	4	12	17	25	Response
Number of all people that use dining hall	1000	1000	1000	1000	1000	1000
Number of students	899	914	908	888	915	904,8
Number of academicians	101	86	92	112	85	95,2
Number of students who use vegetarian and gluten-free dining hall service point	92	86	86	85	91	88
Number of students who use classical dining hall service point	807	828	822	803	824	816,8
Number of students who use ATM	256	278	276	295	298	280,6
Number of total dining hall service	5	5	5	5	5	5
The total time students waiting in the queue without dining area	1181	1142	1590	990	944	1169,4
The total time academicians waiting in the queue without dining area	3	1	1	4	1	2
The average time students waiting in the queue without dining area	1,31	1,249	1,75	1,11	1,031	1,29
The average time academicians waiting in the queue without dining area	0,029	0,011	0,01	0,035	0,011	0,0192
Total time academicians and student waiting in the queue with dining area	3088	2359	3436	2194	2141	2643,6
Avarage academicians and student waiting in the queue with dining area	3,08	2,35	3,4	2,19	2,1	2,624
The average service time of dining hall service point for academicians	2,05	2,093	1,935	1,991	2,153	2,0444
The average service time of dining hall service point for ATM	2,535	2,594	2,739	2,546	2,56	2,5948
The average service time of dining hall service point for VeganAndGlutenFreeService	2,402	2,233	2,36	2,4	2,22	2,323
The average service time of dining hall service point for ClassicalService	2,477	2,42	2,418	2,369	2,377	2,4122
The average service time of dining hall service point for DiningArea	2,165	2,125	2,121	1,2	2,154	1,953
Idle time of dining hall service point for academicians	2830	2658	2560	2664	2754	2693,2
Idle time of dining hall service point for ATM	2388	2117	1982	2136	2174	2159,4
Idle time of dining hall service point for VeganAndGlutenFreeService	2816	2646	2535	2683	2735	2683
Idle time of dining hall service point for ClassicalService	1038	830	750	985	978	916,2
Idle time of dining hall service point for DiningArea	872	703	617	756	783	746,2

Figure 2: Alternative system

- Compute the 95% confidence intervals for the output parameters.

Performance Metrics / Seed value	Mean	StandartDev	Confidence	CI lower bound	CI upper bound
Number of all people that use dining hall	1000	0	0	1000	1000
Number of students	897,8	14,79729705	12,9701644	884,8298356	910,7701644
Number of academicians	102,2	14,79729705	12,9701644	89,2298356	115,1701644
Number of students who use vegetarian and gluten-free dining hall service point	87,4	5,885575588	5,158839667	82,24116033	92,55883967
Number of students who use classical dining hall service point that has more speed	719,4	18,05103875	15,82214235	703,5778577	735,2221423
Number of students who use classical dining hall service point slow	93,8	5,946427499	5,212177739	88,58782226	99,01217774
Number of students who use ATM	244,8	40,61723772	35,6019244	209,1980756	280,4019244
Number of total dining hall service	6	0	0	6	6
The total time students waiting in the queue without dining area	601	43,25274558	37,91200644	563,0879936	638,9120064
The total time academicians waiting in the queue without dining area	1,4	1,496662955	1,311858815	0,088141185	2,711858815
The average time students waiting in the queue	0,667	0,03905893	0,034236032	0,632763968	0,701236032
The average time academicians waiting in the queue	0,0074	0,006858571	0,006011692	0,001388308	0,013411692
Total time academicians and student waiting in the queue with dining area	2364,6	250,6675887	219,7157916	2144,884208	2584,315792
Avarage academicians and student waiting in the queue with dining area	2,36	0,254401258	0,222988437	2,137011563	2,582988437
The average service time of dining hall service point for academicians	1,9656	0,07245578	0,063509124	1,902090876	2,029109124
The average service time of dining hall service point for ATM	2,6508	0,077178754	0,067648917	2,583151083	2,718448917
The average service time of dining hall service point for VeganAndGlutenFreeService	2,2372	0,092976126	0,08149567	2,15570433	2,31869567
The average service time of dining hall service point for ClassicalService_fast	2,706	0,147507288	0,129293463	2,576706537	2,835293463
The average service time of dining hall service point for ClassicalService_slow	2,3994	0,065484655	0,057398776	2,342001224	2,456798776
The average service time of dining hall service point for DiningArea	2,1918	0,097005979	0,085027927	2,106772073	2,276827927
Idle time of dining hall service point for academicians	2701,6	116,5222725	102,1343984	2599,465602	2803,734398
Idle time of dining hall service point for ATM	2194	138,227349	121,1593871	2072,840613	2315,159387
Idle time of dining hall service point for VeganAndGlutenFreeService	2705,8	117,4638668	102,9597269	2602,840273	2808,759727
Idle time of dining hall service point for ClassicalService_fast	1002,2	147,0569958	128,8987715	873,3012285	1131,098772
Idle time of dining hall service point for ClassicalService_slow	2684,2	130,8012232	114,6502205	2569,549779	2798,850221
Idle time of dining hall service point for DiningArea	764,6	124,3166924	108,966383	655,633617	873,566383

Figure 3: SYSTEM DESIGN 1 for 2nd question

Performance Metrics / Seed value	Mean	StandartDev	Confidence	CI lower bound	CI upper bound
Number of all people that use dining hall	1000	0	0	1000	1000
Number of students	904,8	10,14692072	8,89400472	895,9059953	913,6940047
Number of academicians	95,2	10,14692072	8,89400472	86,30599528	104,0940047
Number of students who use vegetarian and gluten-free dining hall service point	88	2,898275349	2,54040367	85,45959633	90,54040367
Number of students who use classical dining hall service point	816,8	9,907572861	8,68421094	808,1157891	825,4842109
Number of students who use ATM	280,6	15,12084654	13,2537628	267,3462372	293,8537628
Number of total dining hall service	5	0	0	5	5
The total time students waiting in the queue without dining area	1169,4	228,3765312	200,177177	969,2228227	1369,577177
The total time academicians waiting in the queue without dining area	2	1,264911064	1,10872306	0,891276941	3,108723059
The average time students waiting in the queue without dining area	1,29	0,25026466	0,21936262	1,070637384	1,509362616
The average time academicians waiting in the queue without dining area	0,0192	0,010628264	0,00931591	0,009884087	0,028515913
Total time academicians and student waiting in the queue with dining area	2643,6	521,7534284	457,328641	2186,271359	3100,928641
Avarage academicians and student waiting in the queue with dining area	2,624	0,51925331	0,45513723	2,168862769	3,079137231
The average service time of dining hall service point for academicians	2,0444	0,076167185	0,06676225	1,977637746	2,111162254
The average service time of dining hall service point for ATM	2,5948	0,074783421	0,06554935	2,529250646	2,660349354
The average service time of dining hall service point for VeganAndGlutenFreeService	2,323	0,080309402	0,070393	2,252606999	2,393393001
The average service time of dining hall service point for ClassicalService	2,4122	0,038467649	0,03371776	2,378482239	2,445917761
The average service time of dining hall service point for DiningArea	1,953	0,376871862	0,33033668	1,622663318	2,283336682
Idle time of dining hall service point for academicians	2693,2	91,91822453	80,5683957	2612,631604	2773,768396
Idle time of dining hall service point for ATM	2159,4	131,3675759	115,146641	2044,253359	2274,546641
Idle time of dining hall service point for VeganAndGlutenFreeService	2683	93,45159175	81,9124266	2601,087573	2764,912427
Idle time of dining hall service point for ClassicalService	916,2	108,111794	94,7624243	821,4375757	1010,962424
Idle time of dining hall service point for DiningArea	746,2	84,65789981	74,2045574	671,9954426	820,4045574

Figure 4: Alternative system design



- Estimate the total number of replications needed to estimate mean output parameters with 10% enhancement (narrowing the CI for 10%).

$$N = (1.96 / 0.9) ^2$$

**N = 17.3136** total number of replications needed to estimate mean output parameters with 10% enhancement

- Compute the 95% prediction intervals for the output parameters.

Performance Metrics / Seed value	Mean	StandartDev	Confidence	CI lower bound	CI upper bound	Prediction lower bound	Prediction upper bound
Number of all people that use dining hall	1000	0	0	1000	1000	1000	1000
Number of students	897,8	14,79729705	12,9701644	884,8298356	910,7701644	868,7972978	926,8027022
Number of academicians	102,2	14,79729705	12,9701644	89,2298356	115,1701644	73,19729778	131,2027022
Number of students who use vegetarian and gluten-free dining hall service point	87,4	5,885575588	5,158839667	82,24116033	92,55883967	75,86427185	98,93572815
Number of students who use classical dining hall service point that has more speed	719,4	18,05103875	15,82214235	703,5778577	735,2221423	684,019964	754,780036
Number of students who use classical dining hall service point slow	93,8	5,946427499	5,212177739	88,58782226	99,01217774	82,1450021	105,4549979
Number of students who use ATM	244,8	40,61723772	35,6019244	209,1980756	280,4019244	165,1902141	324,4097859
Number of total dining hall service	6	0	0	6	6	6	6
The total time students waiting in the queue without dining area	601	43,25274558	37,91200644	563,0879936	638,9120064	516,2246187	685,7753813
The total time academicians waiting in the queue without dining area	1,4	1,496662955	1,311858815	0,088141185	2,711858815	-1,533459391	4,333459391
The average time students waiting in the queue	0,667	0,03905893	0,034236032	0,632763968	0,701236032	0,590444498	0,743555502
The average time academicians waiting in the queue	0,0074	0,006858571	0,006011692	0,001388308	0,013411692	-0,0060428	0,0208428
Total time academicians and student waiting in the queue with dining area	2364,6	250,6675887	219,7157916	2144,884208	2584,315792	1873,291526	2855,908474
Avarage academicians and student waiting in the queue with dining area	2,36	0,254401258	0,222988437	2,137011563	2,582988437	1,861373535	2,858626465
The average service time of dining hall service point for academicians	1,9656	0,07245578	0,063509124	1,902090876	2,029109124	1,823586672	2,107613328
The average service time of dining hall service point for ATM	2,6508	0,077178754	0,067648917	2,583151083	2,718448917	2,499529643	2,802070357
The average service time of dining hall service point for VeganAndGlutenFreeService	2,2372	0,092976126	0,08149567	2,15570433	2,31869567	2,054966793	2,419433207
The average service time of dining hall service point for ClassicalService_fast	2,706	0,147507288	0,129293463	2,576706537	2,835293463	2,416885716	2,995114284
The average service time of dining hall service point for ClassicalService_slow	2,3994	0,065484655	0,057398776	2,342001224	2,456798776	2,271050077	2,527749923
The average service time of dining hall service point for DiningArea	2,1918	0,097005979	0,085027927	2,106772073	2,276827927	2,001668281	2,381931719
Idle time of dining hall service point for academicians	2701,6	116,5222725	102,1343984	2599,465602	2803,734398	2473,216346	2929,983654
Idle time of dining hall service point for ATM	2194	138,227349	121,1593871	2072,840613	2315,159387	1923,074396	2464,925604
Idle time of dining hall service point for VeganAndGlutenFreeService	2705,8	117,4638668	102,9597269	2602,840273	2808,759727	2475,570821	2936,029179
Idle time of dining hall service point for ClassicalService_fast	1002,2	147,0569958	128,8987715	873,3012285	1131,098772	713,9682883	1290,431712
Idle time of dining hall service point for ClassicalService_slow	2684,2	130,8012232	114,6502205	2569,549779	2798,850221	2427,829602	2940,570398
Idle time of dining hall service point for DiningArea	764,6	124,3166924	108,966383	655,633617	873,566383	520,939283	1008,260717

Figure 5: SYSTEM DESIGN 1 for 4th question

Performance Metrics / Seed value	Mean	StandartDev	Confidence	CI lower bound	CI upper bound	Prediction lower bound	Prediction Upper bound
Number of all people that use dining hall	1000	0	0	1000	1000	1000	1000
Number of students	904,8	10,14692072	8,89400472	895,9059953	913,6940047	884,9120354	924,6879646
Number of academicians	95,2	10,14692072	8,89400472	86,30599528	104,0940047	75,3120354	115,0879646
Number of students who use vegetarian and gluten-free dining hall service point	88	2,898275349	2,54040367	85,45959633	90,54040367	82,31938032	93,68061968
Number of students who use classical dining hall service point	816,8	9,907572861	8,68421094	808,1157891	825,4842109	797,3811572	836,2188428
Number of students who use ATM	280,6	15,12084654	13,2537628	267,3462372	293,8537628	250,9631408	310,2368592
Number of total dining hall service	5	0	0	5	5	5	5
The total time students waiting in the queue without dining area	1169,4	228,3765312	200,177177	969,2228227	1369,577177	721,7819989	1617,018001
The total time academicians waiting in the queue without dining area	2	1,264911064	1,10872306	0,891276941	3,108723059	-0,479225686	4,479225686
The average time students waiting in the queue without dining area	1,29	0,25026466	0,21936262	1,070637384	1,509362616	0,799481267	1,780518733
The average time academicians waiting in the queue without dining area	0,0192	0,010628264	0,00931591	0,009884087	0,028515913	-0,001631398	0,040031398
Total time academicians and student waiting in the queue with dining area	2643,6	521,7534284	457,328641	2186,271359	3100,928641	1620,96328	3666,23672
Avarage academicians and student waiting in the queue with dining area	2,624	0,51925331	0,45513723	2,168862769	3,079137231	1,606263512	3,641736488
The average service time of dining hall service point for academicians	2,0444	0,076167185	0,06676225	1,977637746	2,111162254	1,895112318	2,193687682
The average service time of dining hall service point for ATM	2,5948	0,074783421	0,06554935	2,529250646	2,660349354	2,448224496	2,741375504
The average service time of dining hall service point for VeganAndGlutenFreeService	2,323	0,080309402	0,070393	2,252606999	2,393393001	2,165593573	2,480406427
The average service time of dining hall service point for ClassicalService	2,4122	0,038467649	0,03371776	2,378482239	2,445917761	2,336803408	2,487596592
The average service time of dining hall service point for DiningArea	1,953	0,376871862	0,33033668	1,622663318	2,283336682	1,214331151	2,691668849
Idle time of dining hall service point for academicians	2693,2	91,91822453	80,5683957	2612,631604	2773,768396	2513,04028	2873,35972
Idle time of dining hall service point for ATM	2159,4	131,3675759	115,146641	2044,253359	2274,546641	1901,919551	2416,880449
Idle time of dining hall service point for VeganAndGlutenFreeService	2683	93,45159175	81,9124266	2601,087573	2764,912427	2499,83488	2866,16512
Idle time of dining hall service point for ClassicalService	916,2	108,111794	94,7624243	821,4375757	1010,962424	704,3008838	1128,099116
Idle time of dining hall service point for DiningArea	746,2	84,65789981	74,2045574	671,9954426	820,4045574	580,2705164	912,1294836

Figure 6: Alternative System Design

- Estimate the additional replications needed to reduce the half-width of the confidence interval by 10% for the differences of the estimated values of the performance parameters.

Estimate the additional replications

$$= (\textit{standard deviation} / (\textit{half - width} * (1 - \textit{reduction percentage})))^2$$

Output of all parameters are the same. So for example we can do for “Number of students” parameter.

$$\text{Estimate the additional replications} = (10,14/((913,6940047-895,9059953)*0,9))^2 = 1,604$$