IE 30501 – Operations Research II (Spring 2022)

Case Study: A queuing model for Dormitory Washing Machine

Team 2

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1.Introduction

1.1 Research Purpose

Rather than a broad problem across society, we wanted to construct a model for what we experienced in life in queueing and solve the real problem. Thus, we came up with a model of the waiting line for the washing machine. Last year, due to COVID-19, only video classes proceeded, and only limited dormitories were opened to a few students. However, since this semester, as the school began face-to-face classes and accommodated all the students in the dormitory, the number of students using washing machines has also increased. While the number of washing machines is limited, the number of people using the washing machine has increased, and more people have to wait to use the washing machine.

To check the public interest in the problem, we surveyed to see if other people actually feel uncomfortable using the washing machine. As a result, 77.3% of the total 75 respondents said they had experienced inconvenience in using the dormitory coin washing machine. Among the respondents who said they felt uncomfortable, 88.2% said they felt uncomfortable due to time delay, lack of washing machines, and waiting lines. Therefore, we judged that there was a significant need for research on the waiting line of coin washing machines in the dormitory in the school.

1.2 Research Process

The first question raised during the process of setting the research topic was whether this topic is a socially significant study. To confirm this, we surveyed the students who use washing machines. Next, another important question was raised about what kind of data is needed for research and how to collect it. We found that the number of washing machine users by an hour was needed, and we tried to contact related companies and dormitory officials to obtain accurate information, but failed, so instead, we surveyed the washing machine using hours and averaged the data.

As we began to research, we asked ourselves the ultimate question of the goal of this project. In order to solve the actual problem, we decided the goal to find how many washing machines are needed considering the cost of additional washing machines. To this end, it was first necessary to define which model we will apply. The initial research was conducted with the M/M/S model, but we realized our problem situation doesn't follow the assumption of the M/M/s model. To solve this problem, we eventually used an M/M/s/n model. After the model definition, we confirmed whether queuing actually exists and, if so, how long it is.

1.3 Previous Studies

After selecting the topic, we searched for the previous studies on waiting time and queuing models of services. In <The case study on the queue system of bank>, published in 2001, the study is aimed at calculating the work schedule and determining the appropriate size of the bank tellers through the queue model. What is similar to the bank and washing machines is that the arrival time of the service user is not constant and is crowded at a specific time. The bank waiting time increases during lunch and closing hours, and the waiting time for washing machines increase during the evening. The distribution of customer arrival time was identified by examining the interval of customer arrival time. In addition, the number of customers arriving at the bank by dividing the bank operation hours by 30 minutes. Reflecting this, we set a detailed goal for data collection that we need in the problem-specific stage, which is the number of users arriving by time, and for this, we set a time unit as 1 hour. We also checked whether the data we collected statistically follow the exponential function.

In<Modelling Health Care Queue Management System Facing Patients' Impatience using Queuing Theory>, published in 2006, it shows case studies on various queue models that may occur in airports, such as check-in systems and airplane landing traffic. The above actual situation was implemented using the M/M/s model. Specifically, the paper is written about the pre-assumptions for using the M/M/s model in depth: (1) Arrival must come from an infinite or very huge group; (2) Arrival ratio will follow Poisson distribution; (3) Arrivals will follow FIFO; (4) Service times will follow a negative exponential function or constant; (5) Average service speed will be faster than average arrival speed. This paper shows the process of checking whether the above hypothesis fits the actual problem situation, and we applied it to our study. Thus, we realized that the first hypothesis, particularly, does not hold for our current problem situation, it helped us change direction from the M/M/s model to the M/M/s/N model.

2. Method

2.1 Define problem state

There was no data related to the use of washing machines in the dormitory. So, we used the survey results and defined the problem based on male students in building 307.

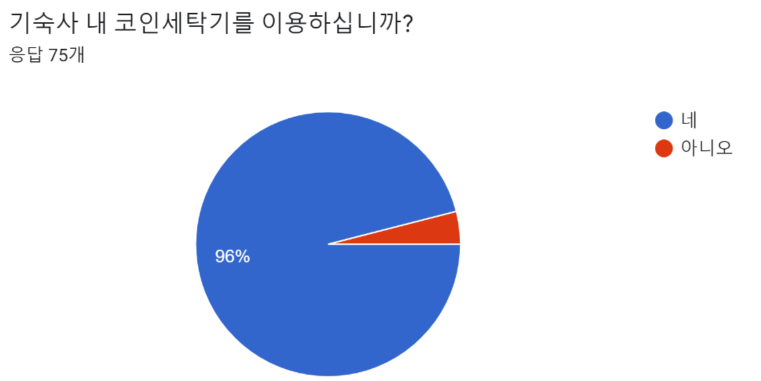
The Poisson distribution is appropriate to use if the following four assumptions are met:

- Assumption 1: The number of events can be counted.
- Assumption 2: The occurrence of events are independent.
- Assumption 3: The average rate at which events occur can be calculated.
- Assumption 4: Two events cannot occur at exactly the same instant in time.

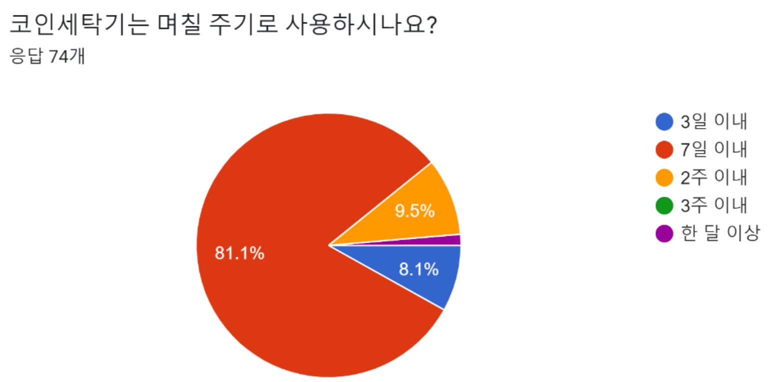
One person's use of a specific washing machine would be called an event. We can count the number of times people use the washing machine, and each person uses the washing machine independently. Also, if we set a time unit, we can calculate the average number of times people use a washing machine during a time unit, and two people cannot use one washing machine at the same time. Since all four assumptions are satisfied, we will use the Poisson distribution, and we define inter-arrival time as exponential.

In building 307, eight people live in each room, and there are four rooms on one floor. And there are 11 floors where male students live from the 3rd to the 13th floors. Therefore, the number of male students living in building 307 is $\frac{8\,people}{room} \times \frac{4\,rooms}{floor} \times 11\,floors = 352\,people.$

According to the survey, 96 percent of students use washing machines in dormitory.



Then, we need to know how often students use washing machines.



Before calculating the average washing cycle, we decided not to consider one person who has the cycle using washing machines is more than a month. This is because the number of times the washing machine is used is small, so there is no effect on queueing for the washing machine.

The results of the survey are as follows:

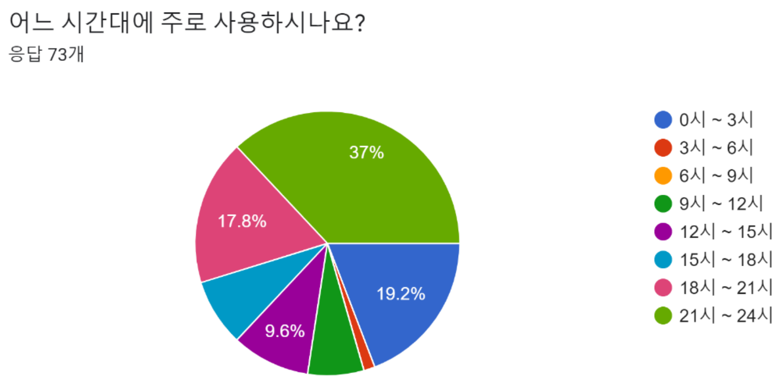
Cycle (days)	Average Cycle (days)	Number of people
1~3	2	6
4~7	5.5	60
8~14	11	7

Due to the characteristics of the survey, it is not possible to ask in detail for the convenience of the survey recipients. Therefore, the average cycle is used.

The minimum common multiple for each Average cycle is 22 days. For 22 days, use 11 times when 2 days of the average cycle, 4 times when 5.5 days of the average cycle, and 2 times when 11 days of the average cycle.

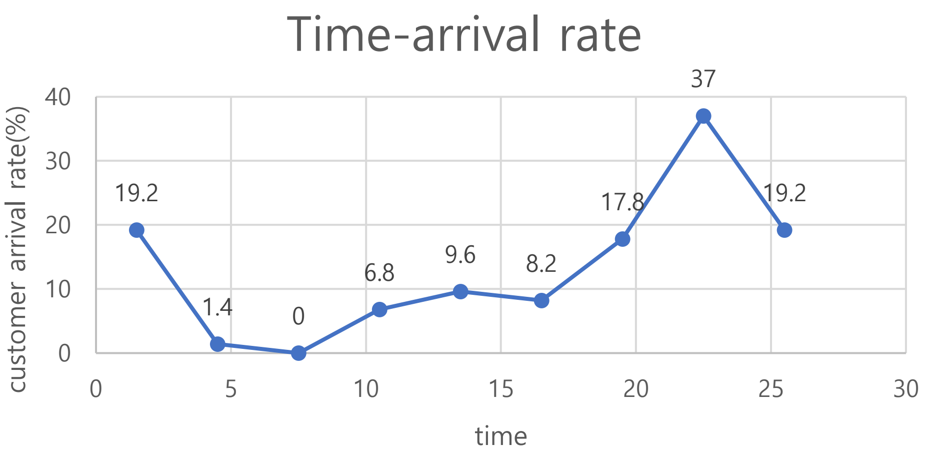
An average number of times one student uses the washing machine in 22days is $\frac{11\times 6+4\times 60+2\times 7}{73}=\frac{320}{73}\ times/22\ days$. So, the average cycle using the washing machine is $22\ days\ \div\ \frac{320}{73}\ times=\frac{803}{160}\ days\ /\ time\ =5.01875\ days\ /\ time\ \approx 5\ days\ /\ time$.

And we should check what time students usually use washing machines.

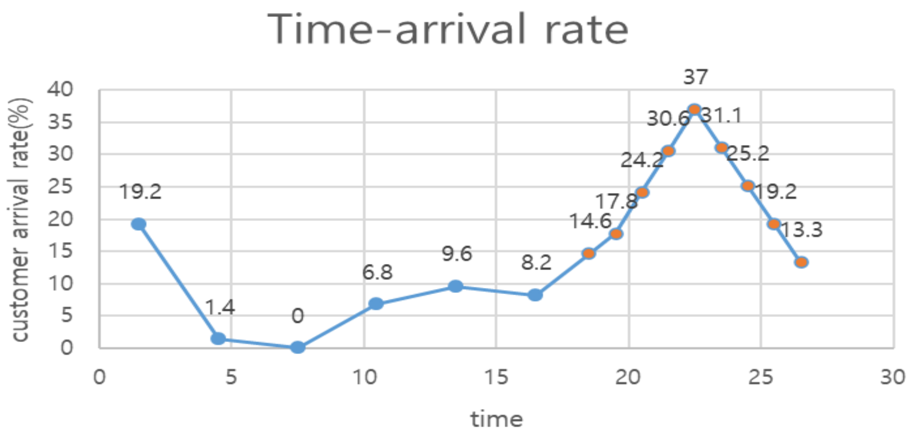


According to the survey, most students use the washing machine between 6 p.m. and 3 a.m. We are interested in times when people feel uncomfortable with the long queue of washing machines. Therefore, it will only be handled from 6 p.m. to 3 a.m.

17.8% of students use the washing machine between 6 p.m. and 9 p.m., 37% of students use the washing machine between 9 p.m. and 12 p.m., and 19.2% of students use the washing machine between 12 p.m. and 3 a.m.



However, students do not use the washing machine equally for three hours. Therefore, we change the time unit to 1 hour. And we assumed that the λ would increase before 10:30 p.m., halfway between 6 p.m. and 3 a.m., and the λ would decrease after 10:30 p.m.



Finally,λ, the expected number of arrivals per unit time, is as follows:

$$\lambda = 352 \times 0.96 \times \frac{1}{5} \times (arrival\ rate) \times \frac{1}{3} [\text{customers / hour(time unit)}]$$

We define service time as deterministic. The washing machine running time is 50 minutes, and we decided that the time it takes for a person to take the laundry is 5 minutes. So, μ, the expected number of customers completing service per unit, is as follows:

$$\mu = \frac{1\text{customer}}{(50+5)\text{minutes}} \times \frac{60\text{minutes}}{1\text{hour}} = \frac{12}{11} \text{customers/hour(timeunit)}$$

The number of servers is 5. And the utilization factor is $\rho = \frac{\lambda}{s\mu}$.

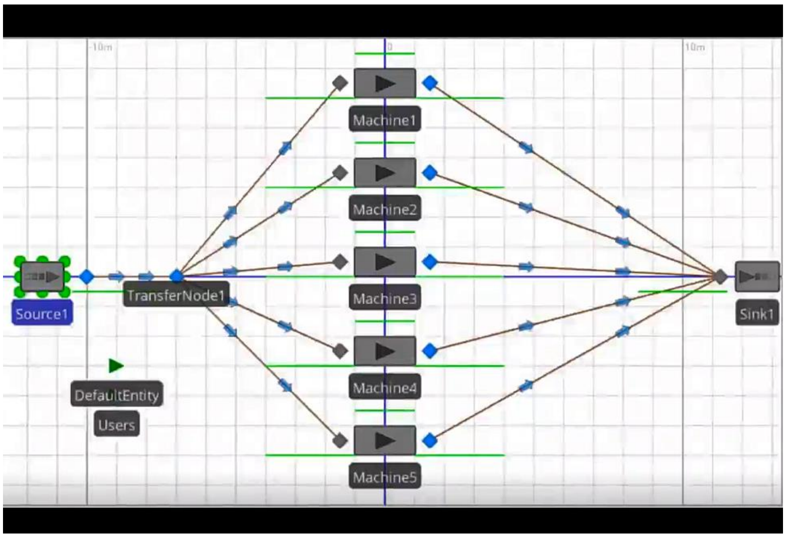
Therefore, the values of λ and ρ between 6 p.m. and 3 a.m. are as follows:

	18:00 ~ 19:00	19:00 ~ 20:00	20:00 ~ 21:00	21:00 ~ 22:00	22:00 ~ 23:00	23:00 ~ 00:00	00:00 ~ 01:00	01:00 ~ 02:00	02:00 ~ 03:00
λ	3.289	4.010	5.452	6.894	8.335	7.006	5.677	4.325	2.996
ρ	0.603	0.735	0.999	1.264	1.528	1.284	1.041	0.793	0.549

2.2 M/M/s/N Modeling

Among various queuing models, we select M/M/s/N model. Because students living in our school dormitory do not wait in a queue infinitely when using the washing machine. We should assume the constraints in the length of the queue. Then how do we set the limit of queue length or capacity of the system? We assume that only one washing machine can wait in line at most. The reason is that if the washing machine is all in use, students wait for the washing machine to finish the fastest before using it. Therefore, our assumption that only up to one person can line up per washing machine is reasonable. And since the washing machine uses a constant 50 minutes, queueing disciplines are FIFO (first-in-first-out).

Then N is the maximum number of customers in the system as 10. Therefore, we will analyze it through the M/M/5/10 model. The simulation figure of our model is as follows.



In M/M/s/N model, the arrival rate λ is divided into true arrival rate and rejection rate.

$$\text{Arrival rate } (\lambda) = \text{"True" arrival rate } (\bar{\lambda}) + \text{Rejection rate } (\lambda_R)$$

$$\lambda = \begin{cases} \bar{\lambda} = \lambda(1 - P_N) & : \text{"True" arrival rate,} \\ \lambda_R = \lambda - \bar{\lambda} & : \text{Rejection rate.} \end{cases}$$

In M/M/s/N model, the utilization factor ρ is divided into true and rejection too.

$$\text{"True" server utilization: } \bar{\rho} = \frac{\bar{\lambda}}{s\mu} < 1$$

The values we derived before are values (λ,ρ) that do not consider the rejection. These values are not real time arrival rate and utilization factor in our model. Therefore, we should derive$\bar{\lambda}$,$\bar{\rho}$.

In M/M/5/10 model, we should derive steady state probability P_n (n=1,2, ... ,10) through arrival rate λ. First, we calculate c_n.

$$c_n = \begin{cases} \dfrac{\left(\lambda/\mu\right)^n}{n!}, & n = 1, 2, \cdots, s, \\ \dfrac{\left(\lambda/\mu\right)^n}{s!\, s^{n-s}}, & n = s+1, \cdots, N, \\ 0, & n = N+1, N+2, \cdots \end{cases}$$

,

```
for n in range(1,s+1):
    list_c.append(((lamda/mu)**n)/math.factorial(n))
for n in range(s+1,N+1):
    list_c.append(((lamda/mu)**n)/(math.factorial(s)*s**(n-s)))
list_cn.append(list_c)
```

Second, we calculate P_0.

$$P_0 = \left[1 + \sum_{n=1}^{N} c_n\right]^{-1} = \left[1 + \sum_{n=1}^{s} \frac{\left(\lambda/\mu\right)^n}{n!} + \frac{\left(\lambda/\mu\right)^s}{s!} \cdot \sum_{n=s+1}^{N} \left(\frac{\lambda}{s\mu}\right)^{n-s}\right]^{-1},$$

```
list_p0=[]
for i in range(len(list3)):
    list_p0.append(1/(1+sum(list_cn[i])))
print(list_p0) #P0 list
```

Third, we calculate P_n. (n=1,2, … ,10)

$$P_n = c_n P_0$$

```
list_pn=[]
for i in range(len(list3)):
    list_p=[]
    for n in range(N):
        list_p.append(list_cn[i][n]*list_p0[i])
    list_pn.append(list_p)
print(list_pn) #p1~p10
```

Forth. we calculate L_q for 9 different time zone

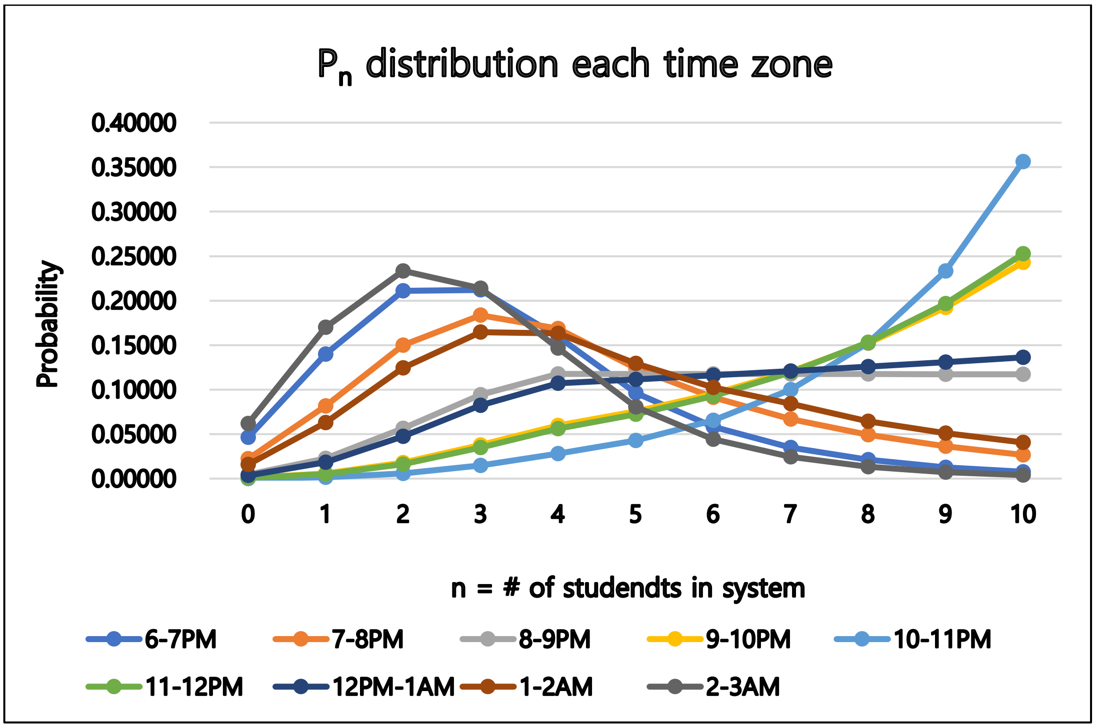
$$L_q = \frac{P_0\left(\lambda/\mu\right)^s\left(\lambda/(s\,\mu)\right)}{s!\left(1-\lambda/(s\,\mu)\right)^2}\left[1-\left(\frac{\lambda}{s\mu}\right)^{N-s+1} - (N-s+1)\left(\frac{\lambda}{s\mu}\right)^{N-s}\left(1-\frac{\lambda}{s\mu}\right)\right],$$

There are our result values.

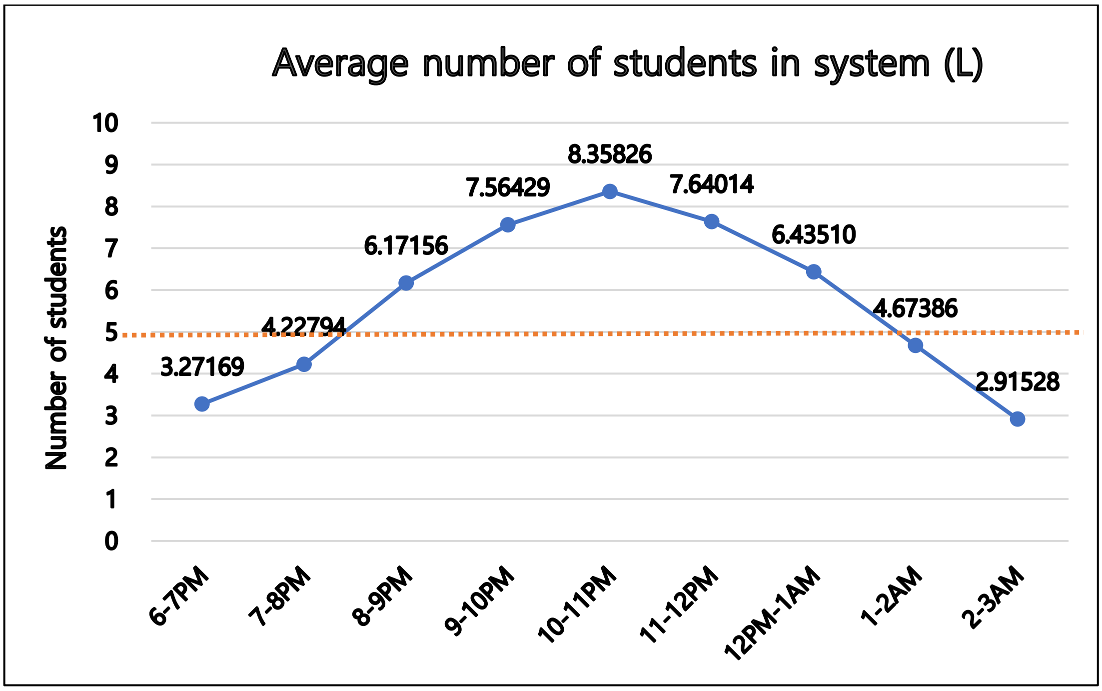
	6-7PM	7-8PM	8-9PM	9-10PM	10-11PM	11-12PM	12PM-1AM	1-2AM	2-3AM
lambda	3.289	4.01	5.452	6.894	8.335	7.006	5.677	4.325	2.996
rho	0.603	0.735	0.999	1.264	1.528	1.284	1.041	0.793	0.549
lambda bar	3.26366	3.90321	4.81261	5.21923	5.36538	5.23651	4.90374	4.14967	2.98394
rho bar	0.59834	0.71559	0.88231	0.95686	0.98365	0.96003	0.89902	0.76077	0.54706
c1	3.015	3.676	4.997	6.319	7.641	6.422	5.204	3.965	2.747
c2	4.545	6.756	12.487	19.966	29.191	20.623	13.541	7.86	3.771
c3	4.568	8.278	20.802	42.055	74.346	44.15	23.488	10.389	3.453
c4	3.443	7.607	25.989	66.437	142.014	70.887	30.558	10.297	2.371
c5	2.076	5.592	25.976	83.965	217.019	91.052	31.804	8.166	1.302
c6	1.252	4.111	25.962	106.116	331.638	116.954	33.102	6.475	0.715
c7	0.755	3.022	25.95	134.112	506.792	150.224	34.453	5.315	0.393
c8	0.455	2.222	25.936	169.493	774.453	192.959	35.858	4.072	0.216
c9	0.275	1.634	25.923	214.209	1183.48	247.85	37.321	3.229	0.119
c10	0.166	1.201	25.91	270.722	1808.534	318.356	38.843	2.56	0.065
P0	0.04641	0.02217	0.00453	0.00090	0.00020	0.00079	0.00351	0.01584	0.06191
P1	0.13991	0.08151	0.02262	0.00567	0.00151	0.00509	0.01825	0.06279	0.17006
P2	0.21091	0.14981	0.05652	0.01792	0.00575	0.01636	0.04748	0.12447	0.23346
P3	0.21198	0.18355	0.09416	0.03774	0.01465	0.03503	0.08236	0.16452	0.21377
P4	0.15978	0.16867	0.11763	0.05962	0.02798	0.05624	0.10716	0.16306	0.14679
P5	0.09634	0.12399	0.11758	0.07535	0.04275	0.07224	0.11153	0.12931	0.08061
P6	0.05810	0.09116	0.11751	0.09522	0.06533	0.09279	0.11608	0.10254	0.04426
P7	0.03504	0.06701	0.11746	0.12035	0.09984	0.11918	0.12081	0.08417	0.02433
P8	0.02111	0.04927	0.11739	0.15209	0.15257	0.15308	0.12574	0.06448	0.01337
P9	0.01276	0.03623	0.11734	0.19222	0.23315	0.19663	0.13087	0.05113	0.00737
P10	0.00770	0.02663	0.11728	0.24293	0.35628	0.25257	0.13621	0.04054	0.00402
Lq	0.28	0.65	1.76	2.78	3.44	2.84	1.94	0.87	0.18
Wq	0.08579	0.16653	0.36571	0.53265	0.64115	0.54235	0.39562	0.20966	0.06032
W	1.00246	1.08320	1.28237	1.44931	1.55781	1.45901	1.31228	1.12632	0.97699
L	3.27169	4.22794	6.17156	7.56429	8.35826	7.64014	6.43510	4.67386	2.91528

The green values are the maximum value of P_n in each time zone.

Then we analyze these result values.



This graph shows that the P_n (probability of the system is in state n) distribution for each time zone. From 9 p.m. to 12 p.m., the P_n is increase continuously and rapidly. In other time zones, the pattern is increase-peak-decrease. They have maximum P_n at close to n= 3. It means that there is the highest probability of three students using washing machines at 6 p.m. to 9 p.m. and 12 p.m. to 3 a.m.



This graph shows the L (an expected number of students in the system). The orange line means that the number of washing machines is 5. In the case of L plot is under the orange line: 6 p.m. to 8 p.m. and 1 a.m. to 3 a.m. There is a high probability of not lining up to use the washing machine. In the case of L plot is above the orange line: 8 p.m. to 1 a.m. There is a high probability of lining up to use the washing machine. The time from 10 p.m.to 11 p.m. people line up most.

3. Analysis

3.1 How to reduce L_q value

Our goal to study this case is to reduce L_q value to reduce the inconvenience of students not being able to use the washing machine immediately. We can approach the solution from two perspectives: Increasing the number of servers and decelerating the arrival rate

3.1.1 Increase the number of servers (# of washing machines)

When we increase s, the L_q will be decreased. We will use the model that we constructed to find the value of s that has no waiting line at any time. In other words, we'll find the **s** that makes the L_q<1 although it is peak time.

s	L_q
5	3.44
7	1.04
8	0.4

At the most peak time (10p.m.-11p.m.), the λ is 8.335. With the existing 5 machines, the waiting line is approximately 3 according to the model. If we increased the number of washing machines to 7, the L_q value will be 1.04 when we calculated it in the same way as earlier. When s≥8, the L_q will be smaller than 1. ($L_q \leq 0.4$). It means no waiting line. However, just increasing it as much as possible can't be a good solution because the cost is also increased. So, we'll find the optimal number of washing machines considering the cost later. (3.2)

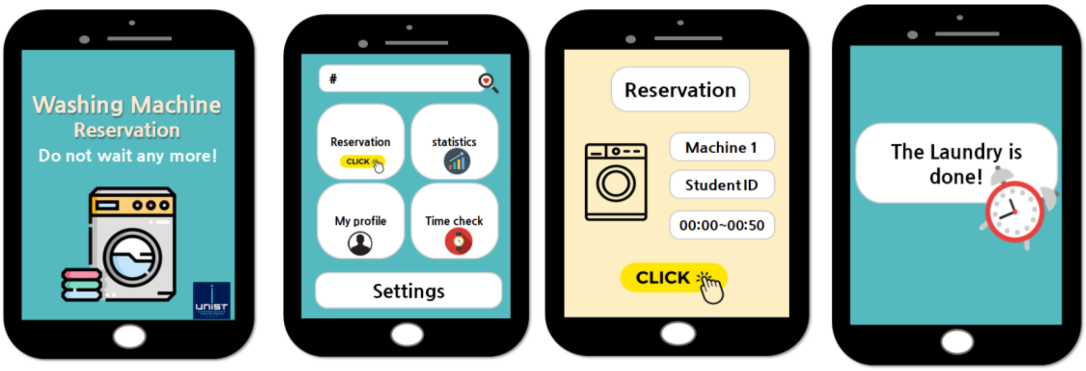
3.1.2. Decelerate the arrival rate

When we decrease λ, the L_q will be decreased. According to the model, the peak time (10p.m. – 11p.m.) λ is 8.335 customers/ hour. When we decrease the arrival rate to smaller than 4 customers/ hour, the L_q will be smaller than 1 with the existing 5 washing machines.

Then, we have to find a way to decelerate the arrival rate. We present two solutions.

- The first solution is an institutional way. Our dormitory consists of homes 1, 2, 3, and 4. Like the 5-day rotation system of the car, if the number of students who use the washing machine is distributed evenly based on the number of homes, such as 9 a.m. to 12 p.m. for No. 1 and from 12 p.m. to 3 p.m. for No. 2, the arrival rate will not exceed 5 in a certain time.

- The second solution is to use an application like clicker which is a library reservation application of UNIST. There are two main functions in this application. First, we can reserve the washing machine for the time to use it. It prevents the arrival rate from increasing at a certain time. Second, the application also provides a notification when the wash ends. It can reduce the time of laundry in the washing machine. In other words, it can reduce the μ value. Furthermore, if the data of consumers accumulated in this way, it will be possible to recommend the time to use it. The below pictures are the prototype of this application.



3.2 Find the optimal number of washing machines in the perspective of cost.

As mentioned in 3.1, we would like to determine the optimal number of washing machines that has a minimum cost based on the model we constructed before. Our model defined that the arrival rate is changed according to the time. The gap in rate between times is quite large since the rate becomes 0 at a specific time. It reduced the average value of λ so that we can't obtain an accurate cost of lost production. Therefore, we defined λ as the average arrival rate of 9 hours of peak time (6pm~3:00am) used by most people and the model assumed that there was no capacity limit in the system to check the continuous change in μ_n as the server increase.

In sum, we use the M/M/s queueing model with λ=5.331 customers/hour and $\mu = \frac{12}{11}$ customers/hour. In this regard, the model will reach a steady-steady state only if

$$\rho = \frac{\lambda}{s\mu} = \frac{5.331}{1.09s} \rightarrow s \geq 5.$$

The total expected cost per hour associated with the multi-washing machine in the dormitory can be expressed by

$$\mathrm{ETC(s)} = \mathrm{C}_1 \times \mathrm{s}_2 \times \mathrm{C}_2 \times \mathrm{L(s)} = 181.9\mathrm{s} + \mathrm{C}_2\mathrm{L(s)}$$

Where ETC(s)= expected cost per hour with s washing machines in the dormitory,

C_1= cost of a new washing machine per hour,

It is the sum of the cost of washing machines and electricity bill and water bill per hour.

Since our dormitory's washing machines are managed by an external company, we want to know the rental cost of each washing machine. However, when we contacted the company, we received the answer that it was an external secret. So, we assume that we bought the washing machine. The cost of *LG Electronics Tromm F13SED* which is the model of washing machine in our dormitory is 3 million won. So,

$$\frac{\text{3million won}}{\text{7years} \times \frac{\text{365 days}}{\text{year}} \times \frac{\text{24 hours}}{\text{day}}} = 48.91 \text{ won}$$

Then based on the expected power consumption of washing machines and experiment using a water meter and electric meter by the experts the electric bill per one washing (1hour) is 40 won and the water bill per one washing (1hour) is 93 won. So, the C_1 is the sum of 48.91, 40, and 93. $\mathrm{C}_1 = 181.9 \text{ won/hour}$.

C_2= Cost of lost operability per waiting machine per hour.

It can't be calculated with some equations. So, we predict the C_2 value as 3 cases (500,333,250). They are based on the charge that needs to wash laundry once. (1000 won.) We assume that the lost operability will lose half/one-third/a quarter of customers per waiting machine. So, the cost will be 500, 333 and 250.

L(s) = average number of laundries in the dormitory when s washing machine is working.

In, M/M/s queue,

$$\mathrm{L(s)} = L_\mathrm{q} + \frac{\lambda}{\mu}$$

To calculate L_q we have to get P_0, first.

$$P_0 = \left[1 + \sum_{n=1}^{s-1} \frac{\left(\lambda/\mu\right)^n}{n!} + \frac{\left(\lambda/\mu\right)^s}{s!} \times \frac{1}{\left(1 - \frac{\lambda}{s\mu}\right)} \right]^{-1}.$$

```python
import math

lamda=5.331
mu =12/11
s=

list_c=[]

for n in range(1,s):
    list_c.append(((lamda/mu)**n)/math.factorial(n))

sum_s=sum(list_c)
mid=((lamda/mu)**s)/math.factorial(s)
end=1/(1-(lamda/(s*mu)))
p_0=1/(1+sum_s+(mid*end))


print(p_0)
```

And then, get the L_q value using the P_0

$$L_q = \frac{P_0 \left(\lambda/\mu\right)^s \left(\lambda/s\mu\right)}{s! \left(1 - \lambda/s\mu\right)^2},$$

```python
one=(lamda/mu)**s
two=lamda/(s*mu)
three=math.factorial(s)*(1-two)**2
lq=(p_0*one*two)/three
print(lq)
```

Then find L(s) using L_q.

$$L(s) = L_q + \frac{\lambda}{\mu},$$

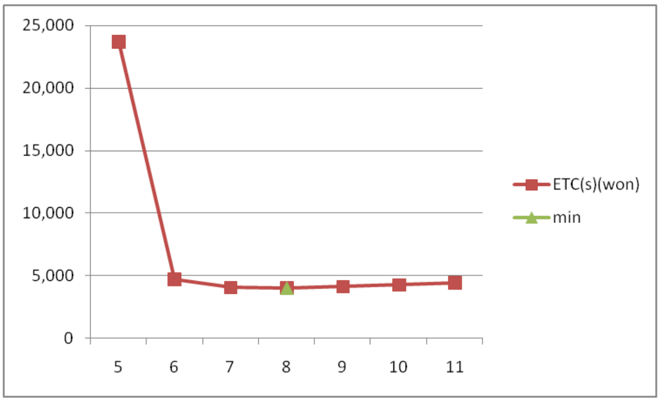
```python
ls=lq+(lamda/mu)
print(round(ls,3))
```

The expected costs per hour for the different number of washing machines are computed below.

1) When C_2=500

s	L(s) requests	ETC(s)(won)
5	45.612	23,715
6	7.29	4,736
7	5.575	4,061
8	5.124	4,017.21
9	4.972	4,122.95
10	4.917	4,277.41
11	4.897	4,449.42

We can represent it as the graph where the x-axis is the number of servers, and the y-axis is ETC(s).

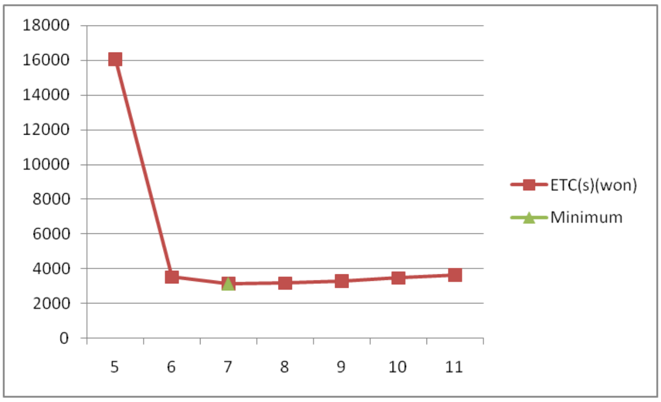


According to the table and graph, the ETC(s) has 23,715 won when a server (washing machine) is 5. As the server is 6, the ETC decreased to 4,736 won and decreased until the server is 8. When servers are 8 the cost is 4,017 won and after 8 (s>8) the ETC(s) is increased. So, the optimal number of the server that has the lowest ETC(s) is $s^* = 8$ when the $C_2 = 500$.

2) When C_2=333

s	L(s) requests	ETC(s)(won)
5	45.612	16,098
6	7.29	3,518
7	5.575	3,129
8	5.124	3,161
9	4.972	3,292
10	4.917	3,456
11	4.897	3,631

The graph where the x-axis is the number of servers and the y-axis is ETC(s) is,

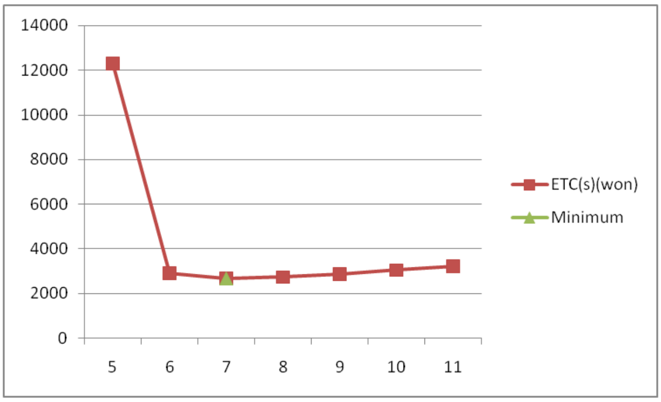


According to the table and graph, the ETC(s) has 16,098 won when servers (washing machine) is 5. As the server is 6, the ETC decreased to 3,518 won and decreased until the server is 7. When serversare7 the cost is 3,129 won and after 7 (s>7) the ETC(s) is increased. So, the optimal number of servers that has the lowest ETC(s) is $s^* = 7$ when the $C_2 = 333$.

3) When C_2=250

s	L(s) requests	ETC(s)(won)
5	45.612	12,312.6
6	7.29	2,913.89
7	5.575	2,667.09
8	5.124	2,736.2
9	4.972	2,880.02
10	4.917	3,048.20
11	4.897	3,225.16

The graph where the x-axis is the number of servers and the y-axis is ETC(s) is,



According to the table and graph, the ETC(s) has 12,312.6won when servers (washing machine) is 5. As the server is 6, the ETC decreased to 2,913 won and decreased until the server is 7. When serversare7 the cost is 2,667 won and after 7 (s>7) the ETC(s) is increased. So, the optimal number of servers that has the lowest ETC(s) is $s^* = 7$ when the $C_2 = 250$.

The optimal value of washing machines is approximately 7~8.

4. Conclusion

As the number of people in the dormitory increased, we felt inconvenience in using the washing machine and defined the problem of queueing for the washing machine in the dormitory. Since it was to solve the problem on campus, not social problem that has data, we conducted on the survey to know the cycle of laundry and the number of users. Based on this, we calculated the arrival rate that changes depending on the time and service time. Based on the model that we conducted, we present two solutions to get the expected number of customer queue value below 1. In other words, there is no waiting line. The first way is to increase the number of washing machines that are servers. Assuming that the Arrival rate does not change, if the number of washing machines is 8 or more, the queue drops below 1. However, increasing the number of them as much as possible is not a good solution because the cost is also increasing as the number of washing machine increases. So, to find the optimal number of washing machines considering the cost, a model was defined based on the previous model. Then we get expected cost per hour with s washing machines in the dormitory and compared them each other.

As a result, seven to eight servers made minimal cost and they are optimal number of washing machine. If the number of washing machines is increased to seven to eight to solve the problem that we can't use washing machine at the time that we want, the number of students using washing machines within the period will increase. It will reduce the cost that loses by loss of customer and students will be able to enjoy improved living standards as the$L_q$value decreases. The second solution is to lower the arrival rate. If the arrival rate is less than 4 for all time, the $L_q$value will not exceed 1 with existing 5 washing machines no matter what time they are used. An institutional method such as a four-part laundry system and a laundry reservation application were proposed as the way to prevent concentration at a specific time. As many as 77% of students are dissatisfied with washing machines system, the quality of life of UNIST students will increase significantly if this problem solved. We suggested it to the dormitory administration to increase the number of washing machines to 7 to 8 or distribute the number of students using the application or the institutional way. Our team finds solutions by applying traditional problem-solving methods to the problems we are experiencing in modern times. If we have a chance next time, we hope to remodel this problem with data with another building and find the more accurate solution per each building to propose it to the dormitory administration and solve this inconvenience that we have experienced directly.