The queueing of Washing Machines in the UNIST Dormitory

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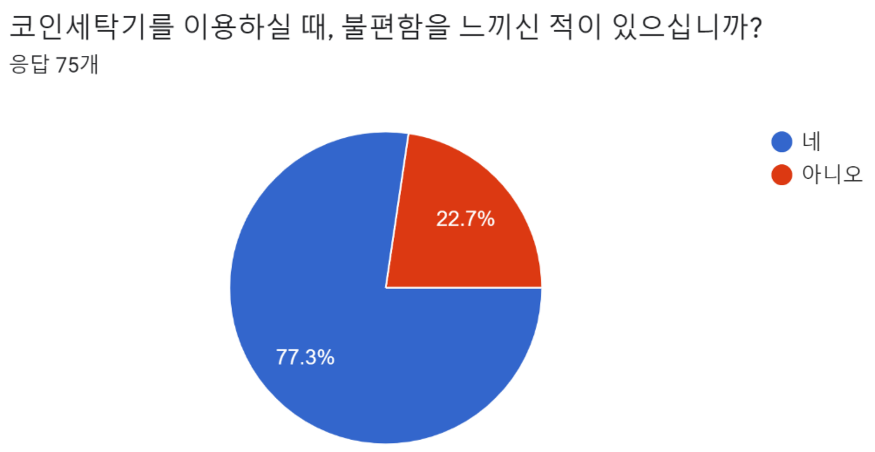
Background

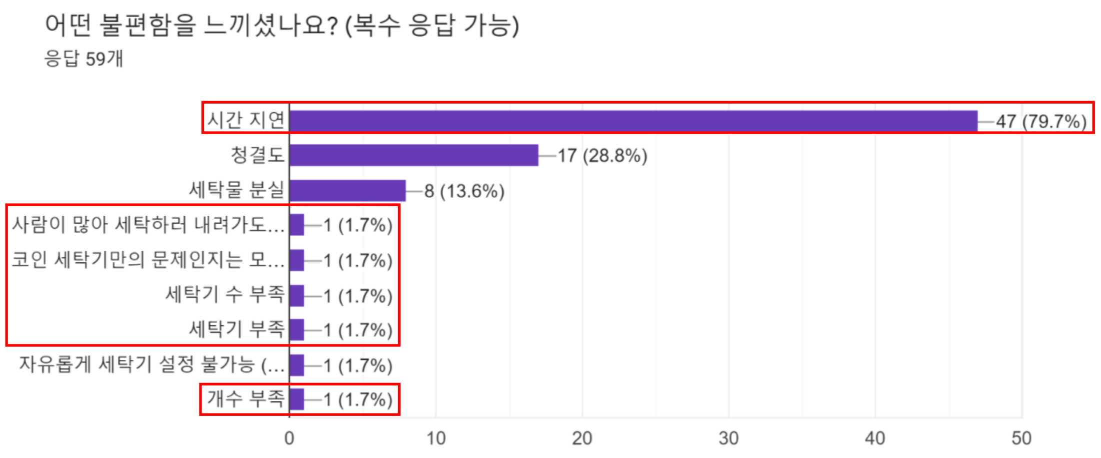
01. Background

Why did we choose this topic?

From this semester, we felt uncomfortable using the washing machine as residents increased.



More than 75% answered they felt **uncomfortable** using washing machines.



88% complained **inconvenience of long waiting times due to the lack of machines**.

02

Problem Set

02. Problem State

How did we collect data?

No data ➡ Use the **survey results**

- **Inter-arrival time is exponential. (Poisson distribution)**

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.

02. Problem State

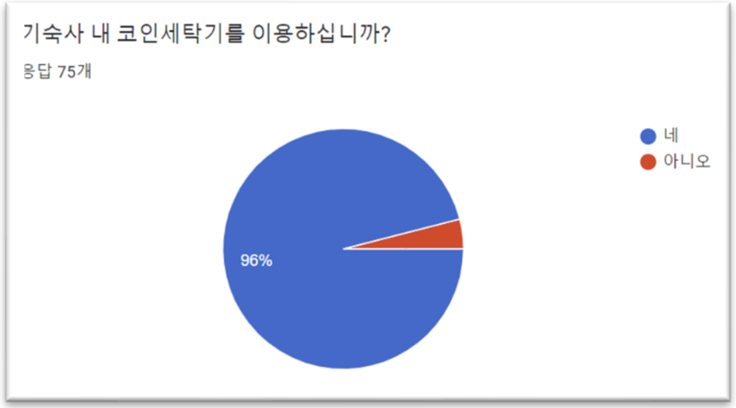
▪ Inter-arrival time is exponential. (Poisson distribution)

Define λ

- Number of male students in 307

32 people/floor × 11 floors = 352 people
(3F – 13F)

- Percentage of use of washing machines in dormitory is 96%.

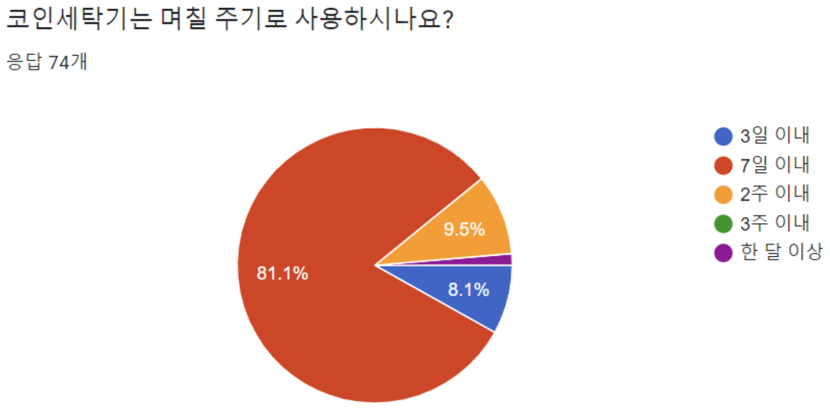


02. Problem State

▪ Inter-arrival time is exponential. (Poisson distribution)

Define λ

- The cycle that students use the washing machine is 5 days. (average)



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

Average number of times one students use the washing machine in 22 days

$: \frac{6 \times 11 + 60 \times 4 + 7 \times 2}{73} = \frac{320}{73}$ times / 22days

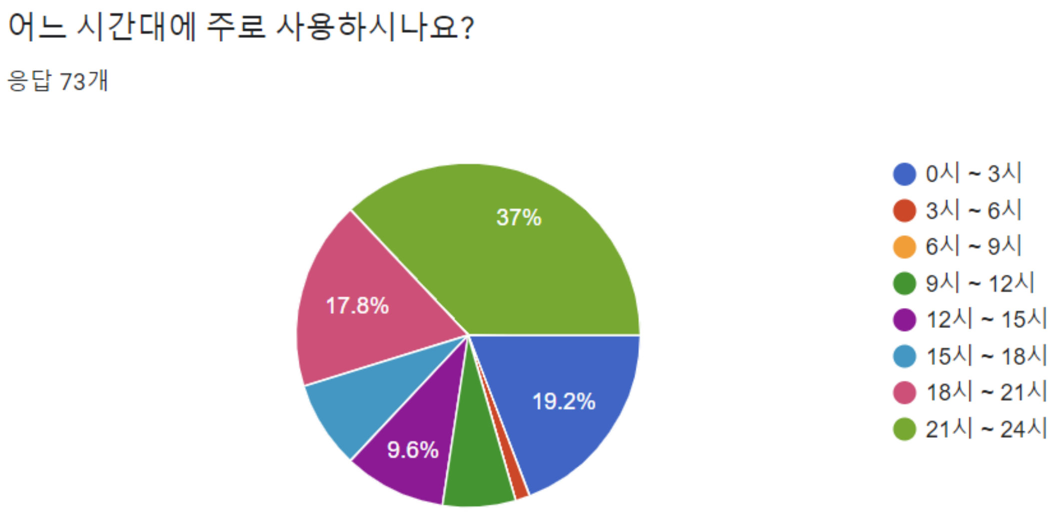
Average cycle using the washing machine

$: 22 \div \frac{320}{73} = 5.01875$ days ≈ 5 days

02. Problem State

▪ Inter-arrival time is exponential. (Poisson distribution)

Define λ



The time when students usually use washing machines

- 18:00~21:00 : 17.8%
- 21:00~24:00 : 37.0%
- 00:00~03:00 : 19.2%

It is 3hour criteria. We set λ change per 1 hour not a 3 hour.

02. Problem State

▪ Inter-arrival time is exponential. (Poisson distribution)

Define λ

The time when students usually use washing machines

- 18:00~21:00 : 17.8% ->λ increase
- 21:00~24:00 : 37.0% ->λ increase during 21:00~22:30, λ decrease 22:30~24:00

(We assume that peak time is 22:30)

- 00:00~03:00 : 19.2% ->λ decrease

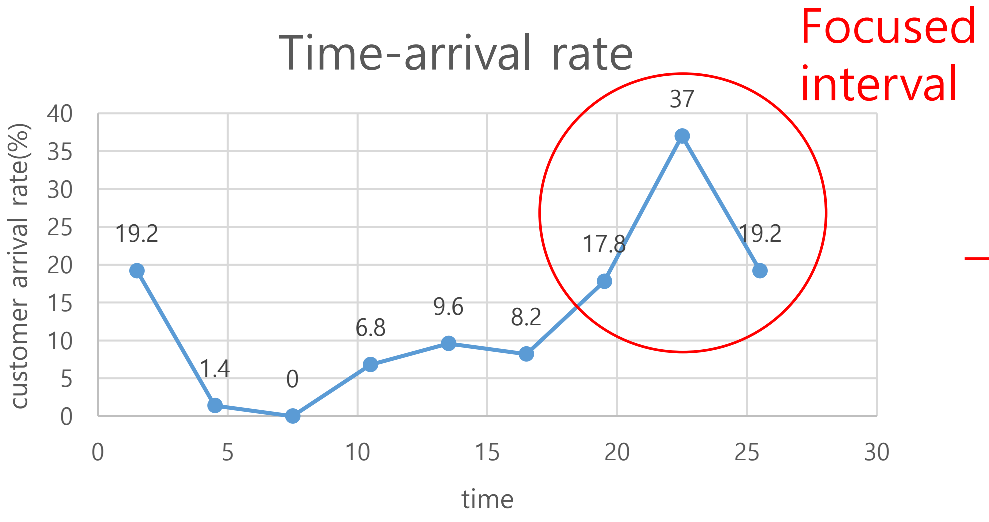
We get 3 different λ per 3 hour, toal is 9.

02. Problem State

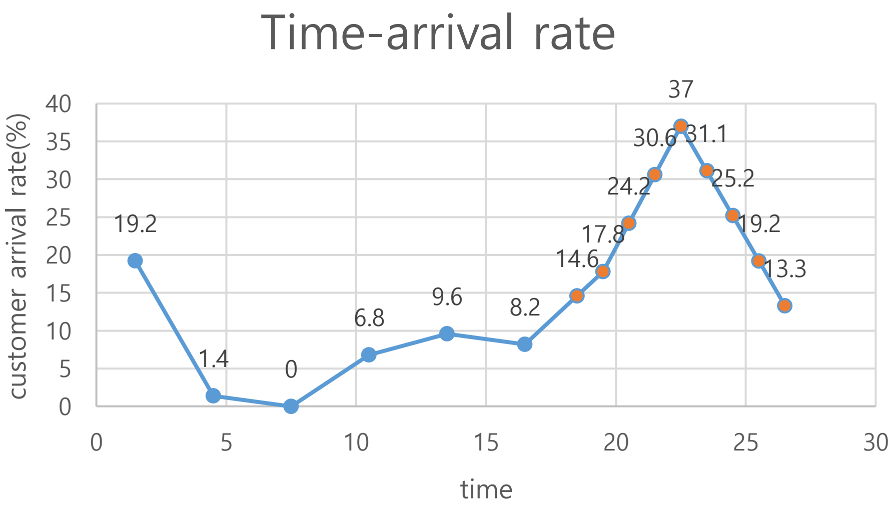
▪ Inter-arrival time is exponential. (Poisson distribution)

Define λ

How to arrival rate change?



Original data(3hour criteria)



Fixed data(1hour criteria)

02. Problem State

- **Inter-arrival time is exponential. (Poisson distribution)**

Define λ

How to determine exact λ?

$\lambda_n = \lambda$: expected number of ariivals per unit time when there are n customers in the system

Washing machine use rate

$$\lambda = \underbrace{352}_{\text{Total user number in bldg.307}} * \underbrace{0.96}_{\text{Washing machine use rate}} * \underbrace{(1/5)}_{\text{Using rate per 1 day}} * (\text{arrival-rate}) * \underbrace{(1/3)}_{\text{per 1 hour}}$$

Using rate per 1 day

per 1 hour

Total user number in bldg.307

02. Problem State

- **Service time is deterministic.**

μ = 50 min (Washing machine running time) + 5 min (taking laundry)

= 55 min = $\frac{11}{12}$hour

- **Number of servers are 5.**

$s = 5$

- **Utilization factor ρ.**

$$\rho = \frac{\lambda}{s\mu}$$

02. Problem State

- Find λ and ρ

	18:00~19:00	19:00~20:00	20:00~21:00	21:00~22:00	22:00~23:00	23:00~24:00	00:00~01:00	01:00~02:00	02:00~03:00
λ	3.29	4.01	5.45	6.89	8.34	7.01	5.68	4.33	3.0
ρ	0.6	0.74	1.0	1.26	1.53	1.28	1.04	0.79	0.55

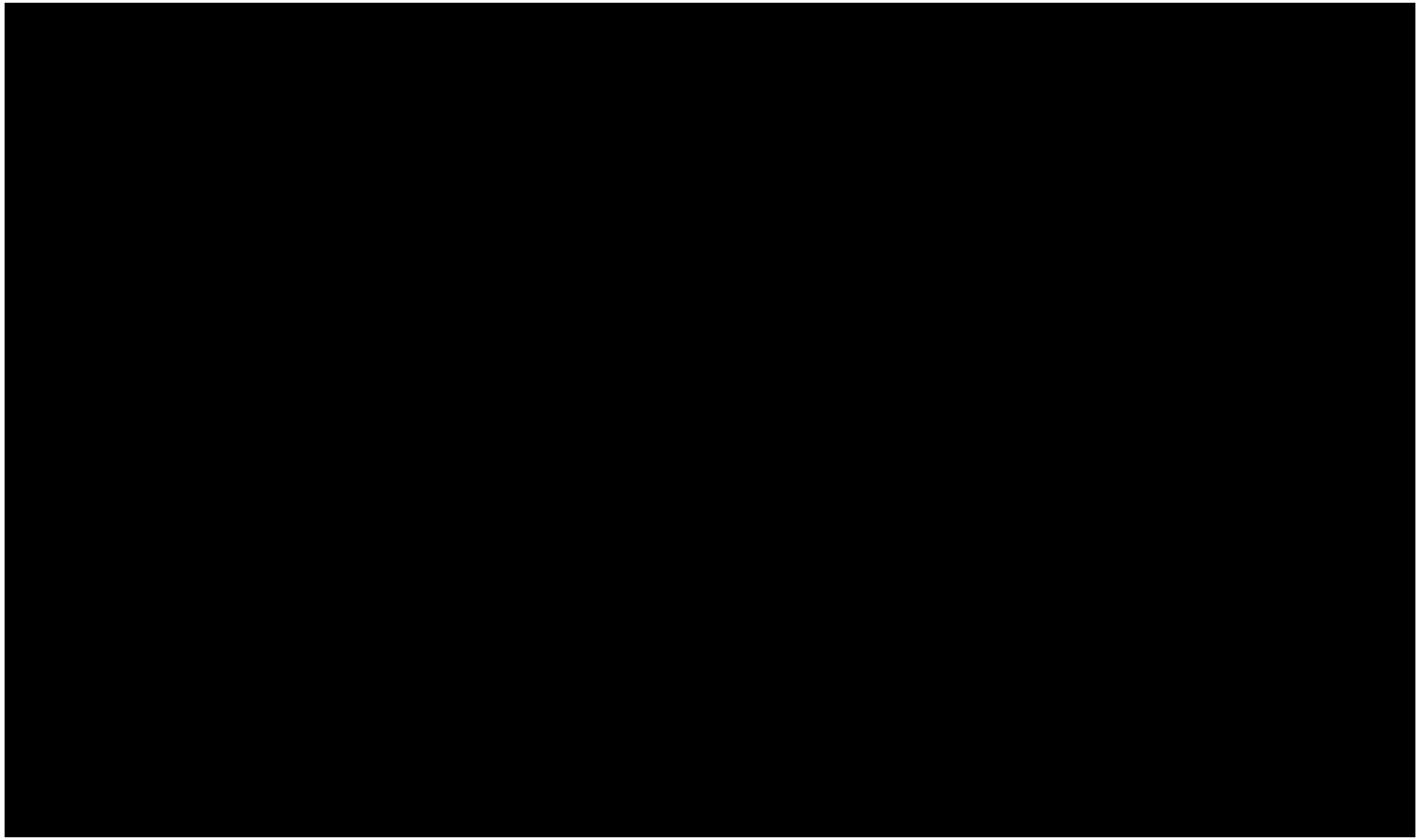
03. Solving the problem

Defining the model

- ## M/M/s/N queuing model.

N = maximum number of customers in the system = 10

(M/M/5/10)



03. Solving the problem

1. Calculating c_n

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

2. Calculating P_0

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

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

	18:00~19:00	19:00~20:00	20:00~21:00	21:00~22:00	22:00~23:00	23:00~24:00	00:00~01:00	01:00~02:00	02:00~03:00
L_q	0.28	0.65	1.76	2.78	3.44	2.84	1.94	0.87	0.18

3. Calculating P_N $\quad P_n = c_n P_0$

```
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
```

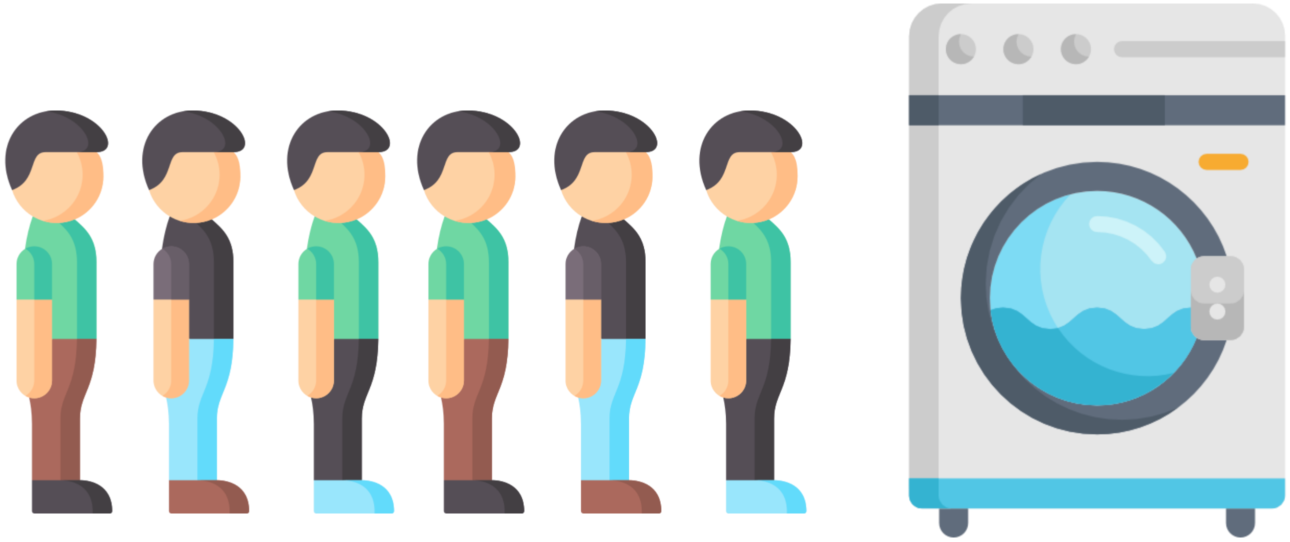
4. Calculating L_q

```
list_Lq=[]
for i in range(len(list3)):
    sum_Lq=0
    for n in range(s,N):
        sum_Lq += (n+1-s)*list_pn[i][n]
    list_Lq.append(sum_Lq)
print(list_Lq) #Lq list
```

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

03. Solving the problem

What we have done



L_q: number of people who are waiting in front of washing machines

3 people should wait for the washing between pm10~am11.

No one should wait for the washing between pm6~am7.

03. Result interpretation

We found there is queuing in the system.

"How long do we have to wait for washing machines?
How many washing machines will need to solve queuing?
Is there any solution to this problem?"

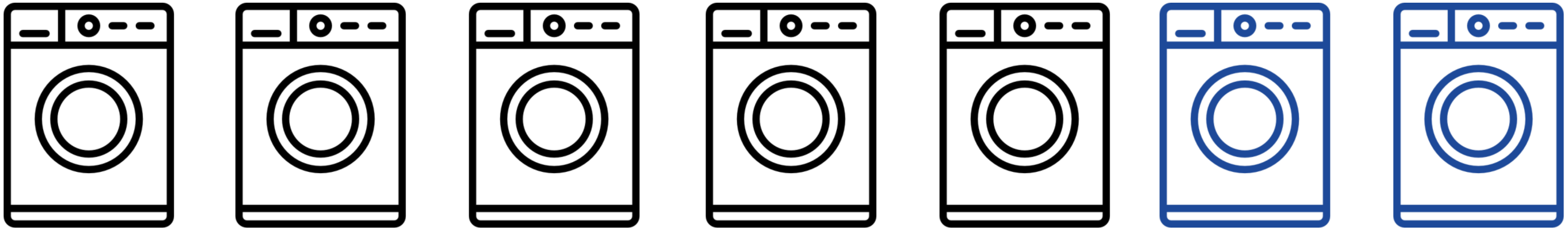
04

Conclusion and Project continuation Plan

04. Conclusion and Project continuation Plan

- Our goal is to reduce the L_q (Length of waiting line)

(1) Increase the number of servers (s)



04. Conclusion and Project continuation Plan

- **Our goal is to reduce the L_q (Length of waiting line)**

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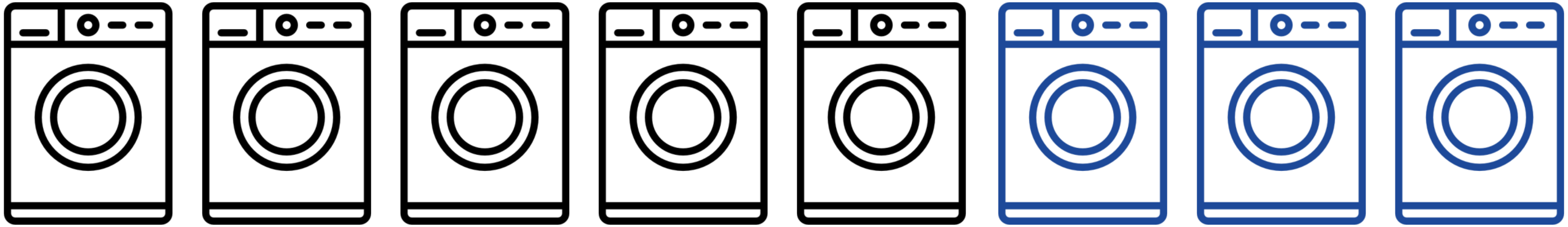


04. Conclusion and Project continuation Plan

- Our goal is to reduce the L_q (Length of waiting line)

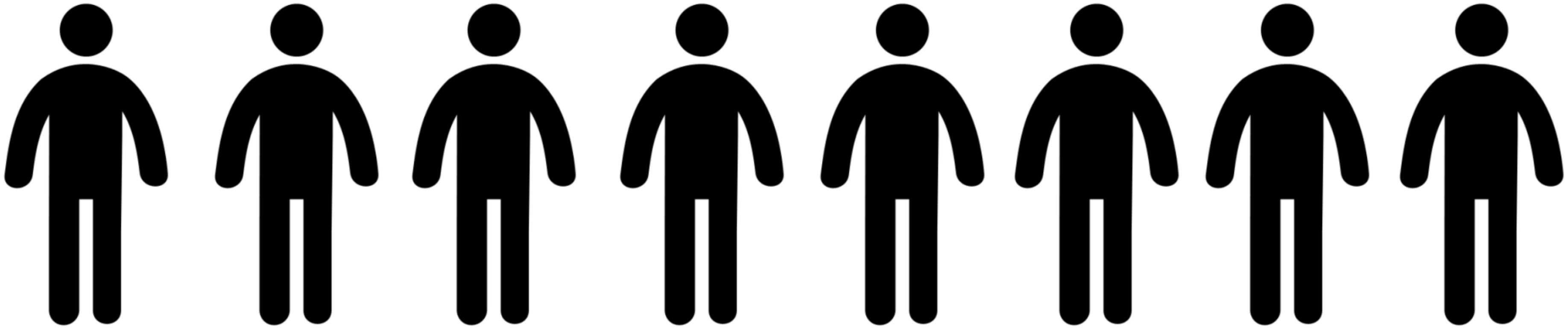
(1) Increase the number of servers (s)

L_q is smaller than 1. No waiting Line!

04. Conclusion and Project continuation Plan

- **Our goal is to reduce the L_q (Length of waiting line)**

(2) Decelerate the arrival rate (λ)



04. Conclusion and Project continuation Plan

- **Our goal is to reduce the L_q (Length of waiting line)**

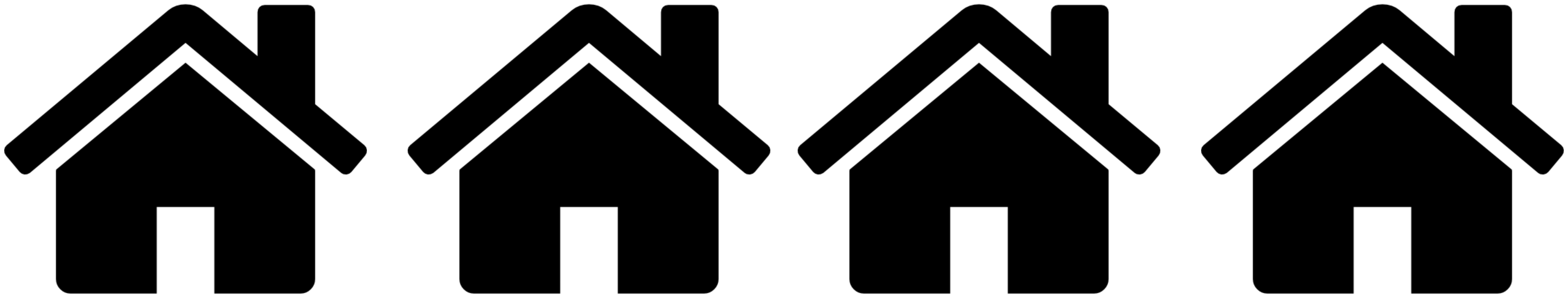
(2) **Decelerate the arrival rate (λ)**

L_q is smaller than 1. No waiting Line!

04. Conclusion and Project continuation Plan

- **Our goal is to reduce the L_q (Length of waiting line)**

(2) Decelerate the arrival rate (λ)



001	**002**	**003**	**004**
9:00 am ~ 12:00 pm	12:00 pm ~ 3:00 pm	3:00 pm ~ 6:00 pm	6:00 pm ~ 9:00 pm

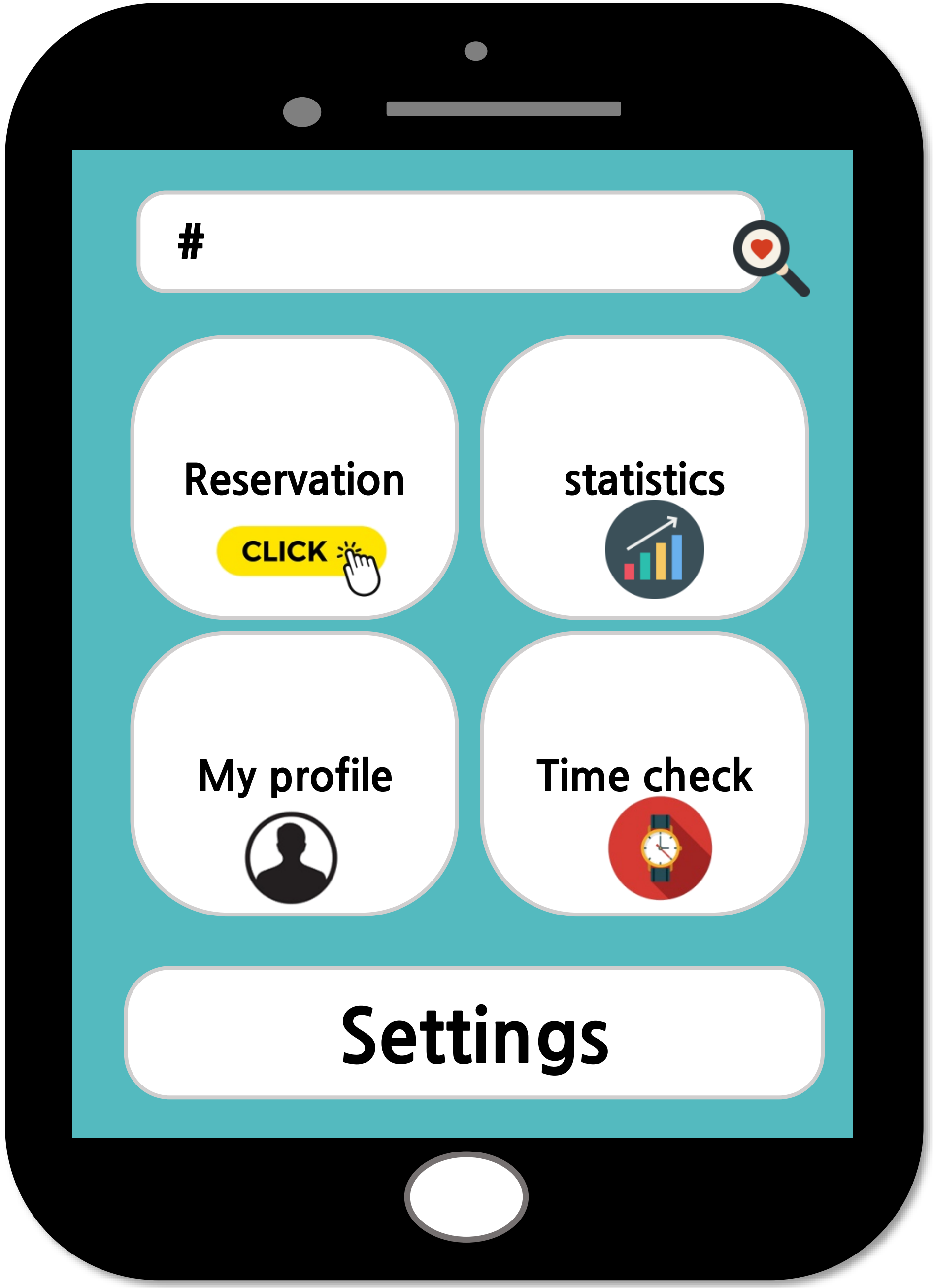
04. Conclusion and Project continuation Plan

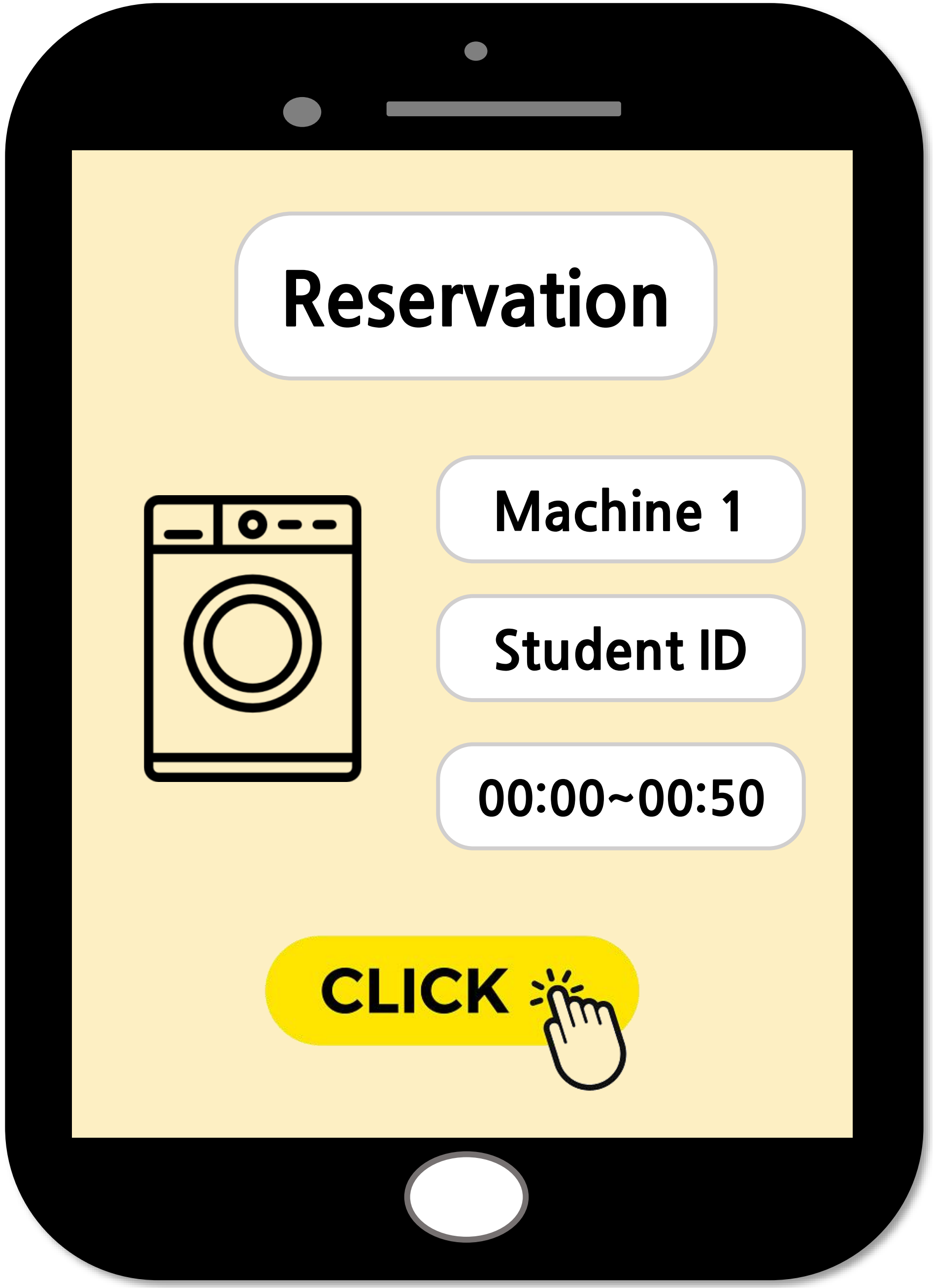
- Our goal is to reduce the L_q (Length of waiting line)

(2) Decelerate the arrival rate (λ)

Washing Machine
Reservation

Do not wait any more!


#
Reservation
CLICK
statistics
My profile
Time check
Settings

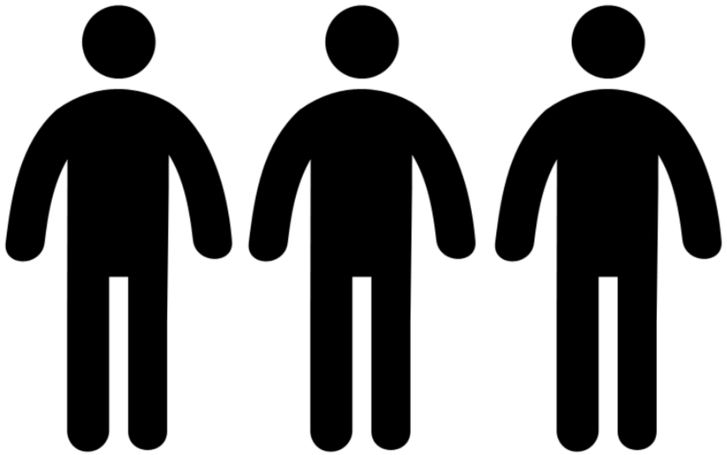

Reservation
Machine 1
Student ID
00:00~00:50
CLICK


The Laundry is done!

04. Conclusion and Project continuation Plan

▪ Total Time spent in queue

(1) The probability of less time spent in queue P(Ω<t)



04. Conclusion and Project continuation Plan

- **Total Time spent in queue**

(2) Compare the cost and Revenue of our solution

Find optimal number of washing machine!

THANK YOU!

Team 2

오지환 , 서민수 : Modeling our problem set

박수빈 : Simulating the model and finalizing the results

신지수 : Finding solutions and planning the future research