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USE OF DISCRETE-EVENT SIMULATION TO IMPROVE INPATIENT PHARMACY QUEUE TIME

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Abstract

The present paper is an understanding on how Discrete Event Simulation (DES) is helpful to improve efficiency by reducing the waiting time in hospital pharmacy outpatients.

By creating a model and establishing its face validity, the present paper tests various scenarios for estimating the possible impact of changes in staffing levels. The main purpose of the simulation model is to reduce the waiting time of the patients' and enhancing the quality of services.

For achieving the main objectives of research, the primary data has been collected from one of the private hospitals in Ahmedabad over a three-month period from June-2021 to August-2021. Discrete Event Simulation (DES) technique has been used for draw the inferences.

The study found that when additional sales staff/s is introduced; preferably pharma-student/s (at the payment of a small stipend), changes in staffing levels; preferably match the arrival pattern of the patients, multilevel staffing strategy and through better time management, the waiting time for the patients can be reduced significantly.

Keywords: *Discrete Event Simulation (DES), Patient Waiting Time, Hospital, Pharmacy Services*

INTRODUCTION

The service system of the pharmacies in hospitals is found complex mainly because of the varied orders (prescriptions) from the customers, and a wide range of staff with role grouping. The advanced technological solutions are to be incorporated to improve the precision and swiftness of drug dispensing. This is also one of the reasons making the service system more complex in the beginning. For every prescribed item, the prescription has to be printed, a bill is to be generated to mention if the medicine is available or if there is another similar medicine available. After that, the total amount of the bill is informed to the patients. If they agree to buy the medicine, the bill is printed, the required medicines are selected and verified, the required dose units are counted and packed and the product is labelled. The prescription is then reverified by a pharmacist, who confirms if a valid dosage regimen has been prescribed before handing out to the patient, hospital ward or department. Such optimization of the organization for dispensing process can be of a lot of assistance to patients, hospital staff and organization.

The dispensary procedure can be modified in many different ways for increasing the efficiency. This could be incorporated by altering the workflows, introducing prioritization systems, and changing the staffing patterns. However, it is difficult to know that which of these changes would benefit and which would be detrimental for the organization. Conducting a series of practical experiments is time-consuming, potentially dangerous, and could create havoc if changes did not work out as planned. Also, if it does not go well, the reversal of the unsuccessful changes could be difficult and demotivating for the staff.

One of the finest methods to evade many potential problems is Computer Simulation Modelling. The likely effect of the incorporated changes made in the process of the dispensaries could be explored without risk disruption. Also, many options could be explored under identical "experimental" conditions which is a rare situation in empirical healthcare research. Modelling needs elucidation and examination of the major interactions and associations involved in a complex system and it leads to a better understanding of the system under study. Computer simulation in healthcare is widely reported in the literature [1–3]. However, while there have been several studies using simulation to study pharmacy systems [4–11], the only one to have specifically examined the hospital pharmacy dispensary was published in 1974 [8]. We therefore wanted to explore the use of simulation in this setting.

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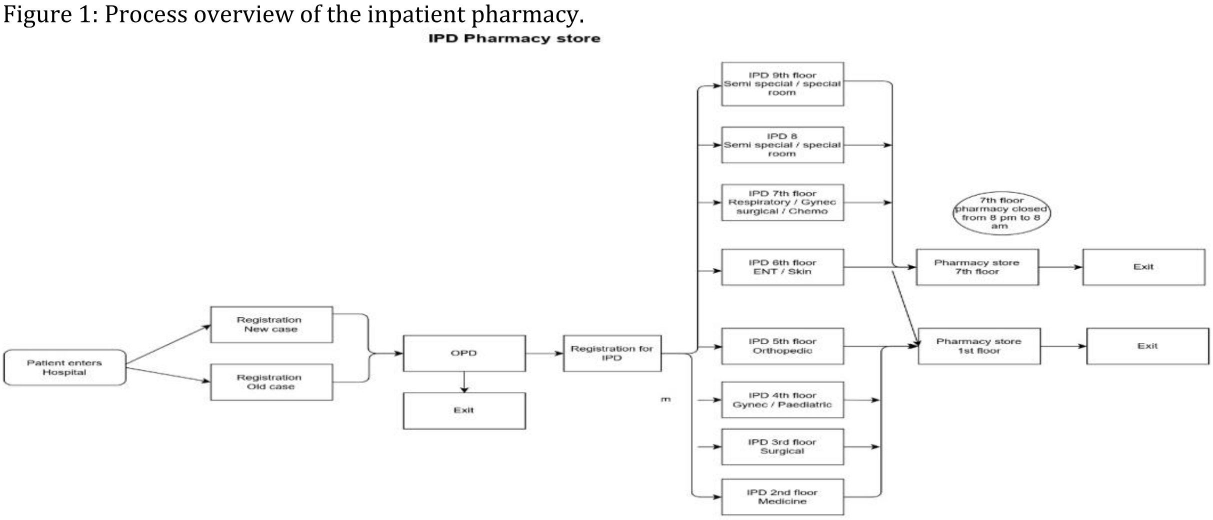
Our objectives were to explore the impact of a range of changes to the outpatient prescription dispensing process on the hospital sites using discrete event simulation and to explore the utility of this approach in this setting.

LITERATURE REVIEW

Simulation and modelling are techniques used to explore and identify alternative solutions, scenarios and their consequences. Many studies use a simulation approach to deal with healthcare problems, to improve its effectiveness (Eldabi et al., 2007). Simulation applications are common in healthcare organizations, particularly in patient-flow management and resource allocation (Jun et al., 1999). According to Brailsford and Hilton (2001), discrete event simulation (DES) is an approach to simulation modelling that is widely used in healthcare. They state that this approach is ideal for demonstrating healthcare problems. Chahal et al., (2013) emphasized that DES can provide valuable insights as an effective decision-making tool to accommodate problem details in healthcare. However, the hybrid model is more efficient when it is used to identify the behavioral impact on operational performance in healthcare organizations. In the same context, Banks et al., (2001) stated that DES has become a popular simulation technique, particularly in finding solutions for healthcare problems, because it is suitable for a dynamic environment and provides a more realistic picture for the situation. Bertolini et al., (2011) attempted to improve the service offered to surgical patients. They used DES to define and analyze a neurosurgery ward's current state to design the future state for the ward.

PROCESS OVERVIEW

The study was carried out at inpatient pharmacies located within a tertiary hospital in Ahmedabad. One pharmacy (first floor) operates 24*7 and second pharmacy (7th floor) operates between 8 am and 8 pm all days. At the time of the study, the first-floor outlet was staffed with up to 10 pharmacists and 1 runners/ assistants and seventh floor outlet was staffed with up to 1 pharmacist and 2 runners/ assistants who worked for 8 hours shifts.
To achieve the main objectives of research, primary data was collected from a private hospital in Ahmedabad over a three-month period from July-2021 to September-2021.
Inpatients take a treatment in any one of seven IPDs before going to the pharmacy store. The doctor visit IPD ward patient and prescribes medicine if he feels the need, which is also inserted by nurse into the computer system, which can be seen by the pharmacist at the pharmacy store. The relative of patient who has been prescribed the medicine stands in the line of the pharmacy store with his case paper/file. When he is called as per the number, he has to give his case paper to the pharmacist, who enters the patient's case number into the computer system and gets a print of the drug prescription. He lets the relative know if the prescribed medicine is available with him or not and its cost if it is available. On agreeing, the patient / relative will be billed and a prescription will be given to the runner to get the required medicines. Through the runner, the medicines will be given to the pharmacist who will check the medicine and label on it. After the verification, the patient will be informed about the purpose and dosage frequency of each prescribed medicine. Also, the patient will be informed about the possible side effects and precautions to be observed while on specific medications. The billed amount is collected and the medicines are handed over to the outpatient. This process is served on a first-come-first-serve basis.
The second to sixth floor admitted patients go to the first-floor pharmacy store to buy medicine and seventh to ninth floor admitted patient go to the seventh-floor pharmacy store to buy medicine. (See figure 1)
Figure 1: Process overview of the inpatient pharmacy.



Model Development

When the process is mapped out within the pharmacy as illustrated in Figure 1, a DES model that represents the workflow processes in inpatient pharmacy has been developed using a commercial simulation software (Arena Professional Edition v14). This model used system characteristics of pharmacy to simulate the activities between the case registrations and the dispensing process. This included the arrival of the patients and the allocation schedule of the existing manpower. _The consolidated process parameters serving as DES model input were based on either 3-month electronically archived data or data collected via a 2-week time motion study.

Out of the total registration cases, 18.64% visit Medicine OPD, 16.90% visit OBG OPD, 14.69% Skin OPD, 13.12% Orthopedic OPD, 10.72% Surgery OPD, and 6.82% ENT OPD. Pediatrics, Psychiatry, Dentistry, Respiratory, Ophthalmology and Physiotherapy OPDs visited below 5% are considered as other OPDs. 12.5% of patients from Medicine OPD, 9% of patients from OBG OPD, 1% of patients from Skin OPD, 7% of patients from Orthopedic OPD, 7% of patients from Surgery OPD, 0.01% of patients from ENT OPD and 4% of patients from other OPD are admitted to the hospital. Table 1 shows percentage of different types of IPDs' patient visit pharmacy store to buy medicines. Analyzing the inpatient pharmacy's 3-month retrospective patient load data, it was observed that the average medicines sold at the 1st floor pharmacy store was 640 per day and 7th floor pharmacy store was 185.

Table 1: Percentage of inpatients to buy medicine from different IPDs.
(7th to 9th floor patient bought medicine on 1st floor between 8 pm to 8 am)

IPD	1st floor pharmacy	7th floor pharmacy
2nd floor	26	
3rd floor	18	
4th floor	17	
5th floor	18	
6th floor	14	
7th floor	3	45
8th floor	2	42
9th floor	2	13

Model Validation

This simulation model was run for 500 replications. For model validation purpose, a 95% confidence interval was calculated. Observed mean waiting time of 1st floor pharmacy in the real-life was 25.18 minutes (95% confidence interval 24.26 to 26.1 minutes) and comparable to those estimated by the baseline model: 25.45 minutes (95% confidence interval 24.2 to 26.7 minutes). Observed mean waiting time of 7th floor pharmacy in the real-life was 18.23 minutes (95% confidence interval 17.44 to 19.02 minutes) and comparable to those estimated by the baseline model: 18.55 minutes (95% confidence interval 17.63 to 19.47 minutes). The actual number of patients who bought medicine was 640 at 1st floor medicine store and 185 at 7th floor medicine store, as per the model, bills generated from the 1st floor store were 652 and 7th floor store were 191.

'What-if' Analysis / Experimentation

Actual man-power at pharmacy store is shown in table 5.

(a) Adding an additional part time sales staff/s

If an additional part time sales staff/s preferably pharma-student/s (by paying a small stipend) is introduced in peak-hours: 10 am to 2 pm and 5 pm to 8 pm (denoted by strategies 1 to 4, see table 6 to 9), we can open one/two extra windows on 1st floor pharmacy and one extra window on 7th floor pharmacy to reduce waiting time of inpatient. The simulation output is compared with that of the baseline model.

(b) Changes in staffing levels

If the manpower could match the arrival pattern of the patients, there could be a reduction in the waiting time of the patients. However, with the limited staff on the 7th floor pharmacy, changes are not possible. Various strategies regarding manpower scheduling were tried, tested and derived. The derivation process was done on a trial-and-error basis. Required modifications were made in the earlier processes. Two manpower scheduling techniques were developed and their respective effect on the patient cycle time and manpower requirements were projected with the DES model. (Tables 10 and 11)

(c) Multilevel staffing strategy

Bringing about a change in the staffing level reduces the time and if sales staff/s are added during the peak time then patient waiting time can be reduced even further. We can add sales staff/s in two new manpower scheduling strategies (see table 12 to 19). This derivation was done through trial-and-error basis. The simulation output was compared with the baseline model and change in the staffing level strategy.

RESULT

(a) Adding an additional part time sales staff/s

As expected, it was found that the addition of extra staff improved the current system and decreased mean waiting time. When we introduce one part time sales staff on 1st floor pharmacy, mean waiting time on 1st floor pharmacy: 16.63 minutes (95% confidence interval 16.52 to 16.63 minutes) and mean waiting time on 7th floor pharmacy: 18.62 minutes (95% confidence interval 18.51 to 18.73 minutes). When we introduce one part time sales staff on 1st floor and 7th floor pharmacy, mean waiting time on 1st floor pharmacy: 16.65 minutes (95% confidence interval 16.52 to 16.63 minutes) and mean waiting time on 7th floor pharmacy: 11.12 minutes (95% confidence interval 11.03 to 11.21 minutes). When we introduce two part time sales staff on 1st floor pharmacy, mean waiting time on 1st floor pharmacy: 13.89 minutes (95% confidence interval 13.80 to 13.98 minutes) and mean waiting time on 7th floor pharmacy: 18.62 minutes (95% confidence interval 18.51 to 18.73 minutes). When we introduce two part time sales staff on 1st floor and one part time sales staff on 7th floor pharmacy, mean waiting time on 1st floor pharmacy: 13.83 minutes (95% confidence interval 13.73 to 13.93 minutes) and mean waiting time on 7th floor pharmacy: 10.92 minutes (95% confidence interval 10.82 to 10.92 minutes). Thus, we can say that this technique highly reduces the patient's waiting time. (See table 2 and figure 2 and 3)

Table 2: Mean waiting time, minutes (95% CI)

Strategy	1st floor pharmacy	7th floor pharmacy
Actual Waiting Time	25.52 (25.40 to 25.64)	18.59 (18.48 to 18.70)
Strategy 1: Adding 1-part timer on 1st floor pharmacy	16.63 (16.52 to 16.63)	18.62 (18.51 to 18.73)
Strategy 2: Adding 1-part timer on 1st and 7th floor pharmacy	16.65 (16.55 to 16.65)	11.12 (11.03 to 11.21)
Strategy 3: Adding 2-part timer on 1st floor pharmacy	13.89 (13.80 to 13.98)	18.62 (18.51 to 18.73)
Strategy 4: Adding 2-part timer on 1st and 1-part timer on 7th floor pharmacy	13.83 (13.73 to 13.93)	10.92 (10.82 to 10.92)

Figure 2: 1st floor pharmacy waiting time

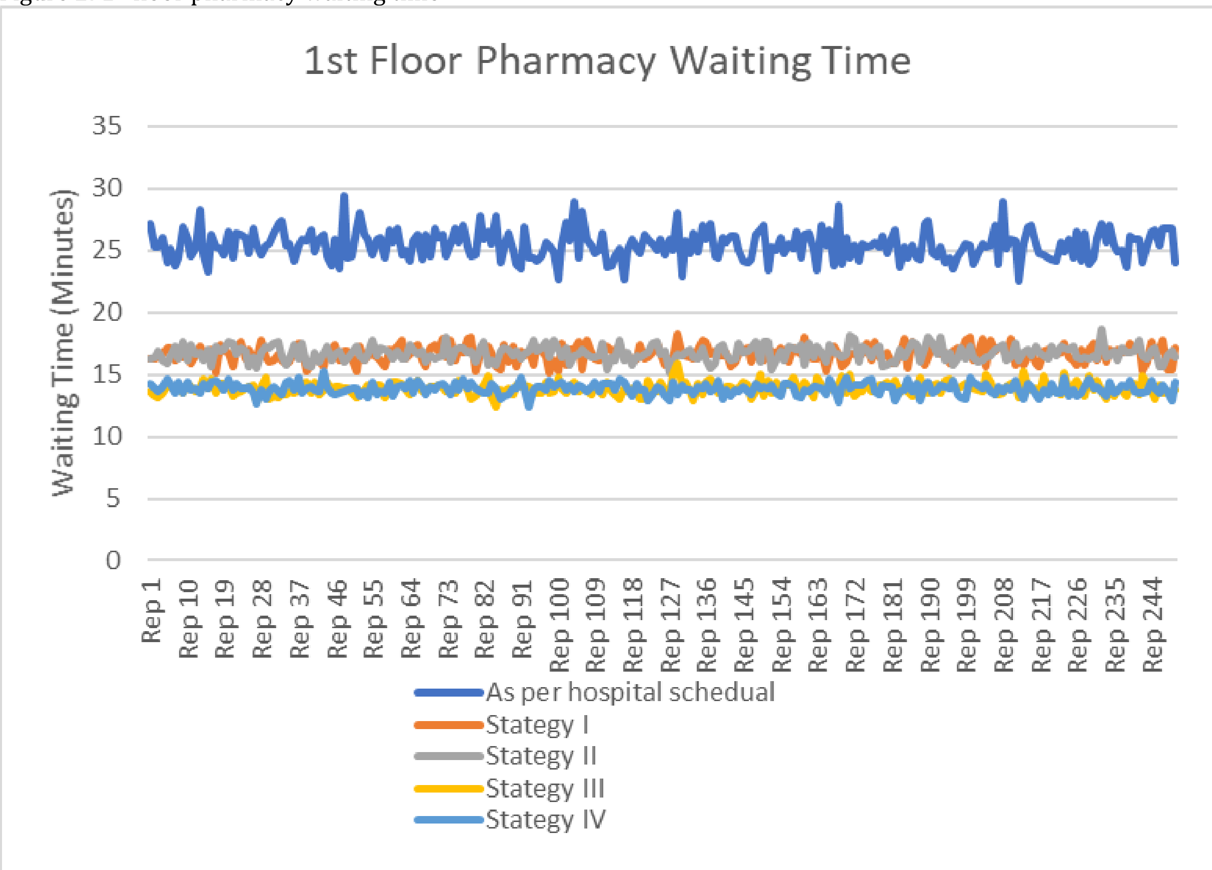


Figure 3: 7th floor pharmacy waiting time

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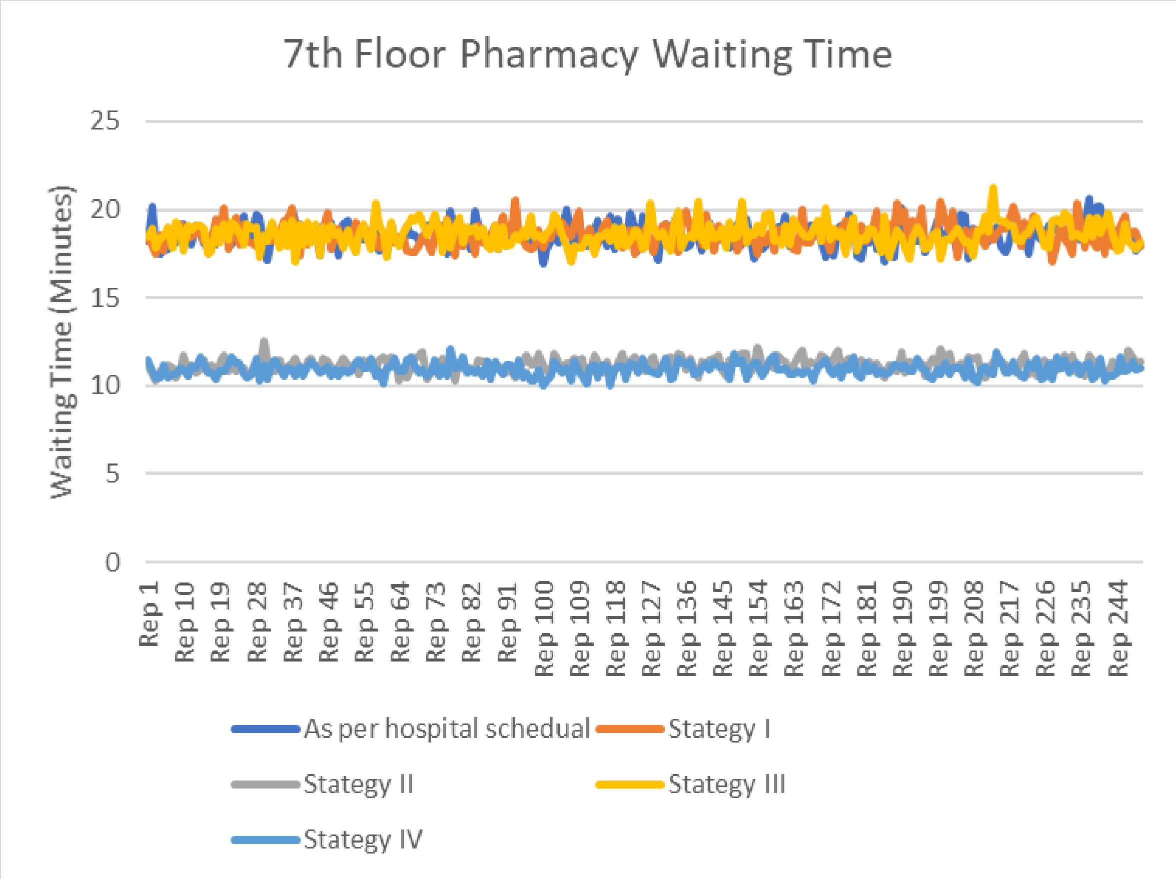


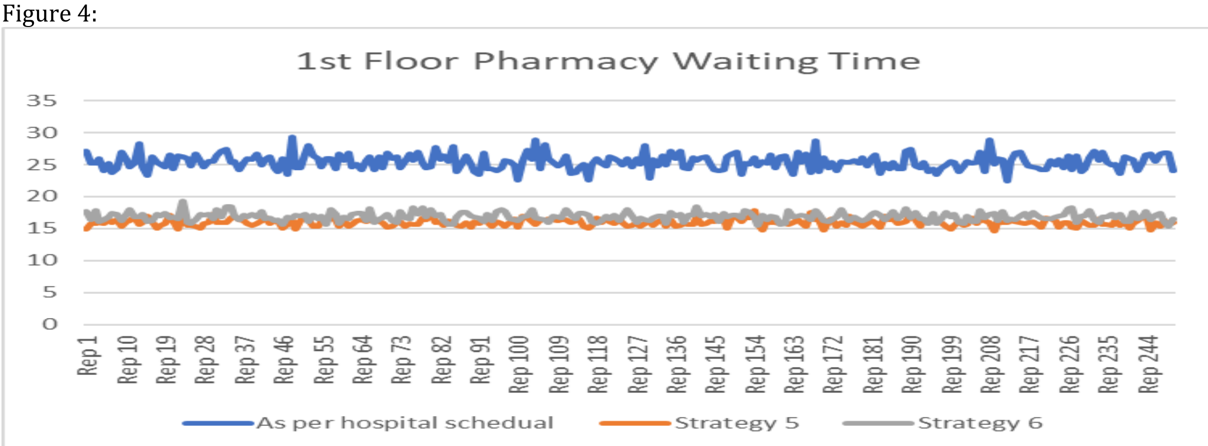
(b) Changes in staffing levels

We found that, changes in staffing schedule techniques that matched the arrival pattern of the patients, could improve the performance of the system. Regardless of two new manpower scheduling strategies (denoted by strategies 5 and 6), decrease in mean waiting time. When we introduce strategy 5, mean waiting time on 1st floor pharmacy: 15.98 minutes (95% confidence interval 15.85 to 16.11 minutes) and mean waiting time on 7th floor pharmacy: 18.67 minutes (95% confidence interval 18.53 to 18.81 minutes). When we introduce strategy 6, mean waiting time on 1st floor pharmacy: 16.88 minutes (95% confidence interval 15.85 to 16.11 minutes) and mean waiting time on 7th floor pharmacy: 18.70 minutes (95% confidence interval 18.55 to 18.85 minutes). (See table 3 and figure 4)

Table 3: Mean waiting time, minutes (95% CI)

Strategy	1st floor pharmacy	7th floor pharmacy
Actual Waiting Time	25.52 (25.40 to 25.64)	18.59 (18.48 to 18.70)
Strategy 5	15.98 (15.85 to 16.11)	18.67 (18.53 to 18.81)
Strategy 6	16.88 (16.73 to 17.03)	18.70 (18.55 to 18.85)

Figure 4:



(c) Multilevel staffing strategy

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We found that, multilevel staffing strategy (denoted by strategies 7 to 14), highly decrease in mean waiting time.

When we introduce strategy 7, mean waiting time on 1st floor pharmacy: 12.63 minutes (95% confidence interval 12.52 to 12.74 minutes) and mean waiting time on 7th floor pharmacy: 18.64 minutes (95% confidence interval 18.55 to 18.73 minutes). When we introduce strategy 8, mean waiting time on 1st floor pharmacy: 12.56 minutes (95% confidence interval 12.44 to 12.68 minutes) and mean waiting time on 7th floor pharmacy: 10.95 minutes (95% confidence interval 10.84 to 11.06 minutes). When we introduce strategy 9, mean waiting time on 1st floor pharmacy: 10.66 minutes (95% confidence interval 10.57 to 10.75 minutes) and mean waiting time on 7th floor pharmacy: 18.60 minutes (95% confidence interval 18.52 to 18.68 minutes). When we introduce strategy 10, mean waiting time on 1st floor pharmacy: 10.70 minutes (95% confidence interval 10.81 to 11.03 minutes) and mean waiting time on 7th floor pharmacy: 10.92 minutes (95% confidence interval 18.55 to 18.85 minutes).

When we introduce strategy 11, mean waiting time on 1st floor pharmacy: 12.04 minutes (95% confidence interval 11.94 to 12.14 minutes) and mean waiting time on 7th floor pharmacy: 18.70 minutes (95% confidence interval 18.61 to 18.79 minutes). When we introduce strategy 12, mean waiting time on 1st floor pharmacy: 12.01 minutes (95% confidence interval 11.89 to 12.13 minutes) and mean waiting time on 7th floor pharmacy: 10.91 minutes (95% confidence interval 10.81 to 11.01 minutes). When we introduce strategy 13, mean waiting time on 1st floor pharmacy: 9.95 minutes (95% confidence interval 9.84 to 10.06 minutes) and mean waiting time on 7th floor pharmacy: 18.62 minutes (95% confidence interval 18.53 to 18.71 minutes). When we introduce strategy 14, mean waiting time on 1st floor pharmacy: 9.96 minutes (95% confidence interval 9.86 to 10.06 minutes) and mean waiting time on 7th floor pharmacy: 10.89 minutes (95% confidence interval 10.78 to 11 minutes). (See table 4 and figure 5 and 6)

Table 4: Mean waiting time, minutes (95% CI)

Strategy	1st floor pharmacy	7th floor pharmacy
Actual Waiting Time	25.52 (25.40 to 25.64)	18.59 (18.48 to 18.70)
Strategy 7: (strategy 5 + 1 Part timer on 1st floor)	12.63 (12.52 to 12.74)	18.64 (18.55 to 18.73)
Strategy 8: (strategy 5 + 1 Part timer on 1st and 7th floor)	12.56 (12.44 to 12.68)	10.95 (10.84 to 11.06)
Strategy 9: (strategy 5 + 2 Part timer on 1st floor)	10.66 (10.57 to 10.75)	18.60 (18.52 to 18.68)
Strategy 10: (strategy 5 + 2 Part timer on 1st floor and 1 Part timer on 7th floor)	10.70 (10.60 to 10.80)	10.92 (10.81 to 11.03)
Strategy 11: (strategy 6 + 1 Part timer on 1st floor)	12.04 (11.94 to 12.14)	18.70 (18.61 to 18.79)
Strategy 12: (strategy 6 + 1 Part timer on 1st and 7th floor)	12.01 (11.89 to 12.13)	10.91 (10.81 to 11.01)
Strategy 13: (strategy 6 + 2 Part timer on 1st floor)	9.95 (9.84 to 10.06)	18.62 (18.53 to 18.71)
Strategy 14: (strategy 6 + 2 Part timer on 1st floor and 1 Part timer on 7th floor)	9.96 (9.86 to 10.06)	10.89 (10.78 to 11)

Figure 5:

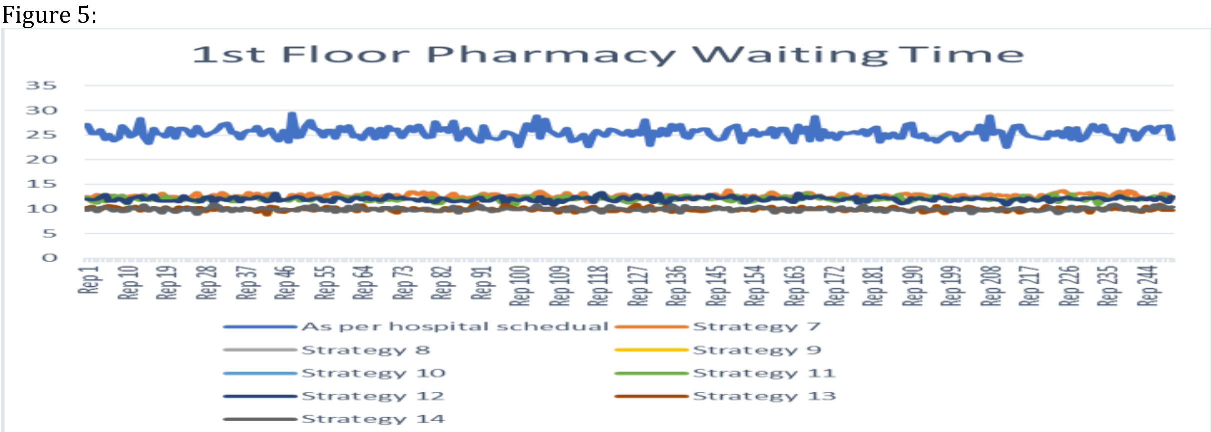
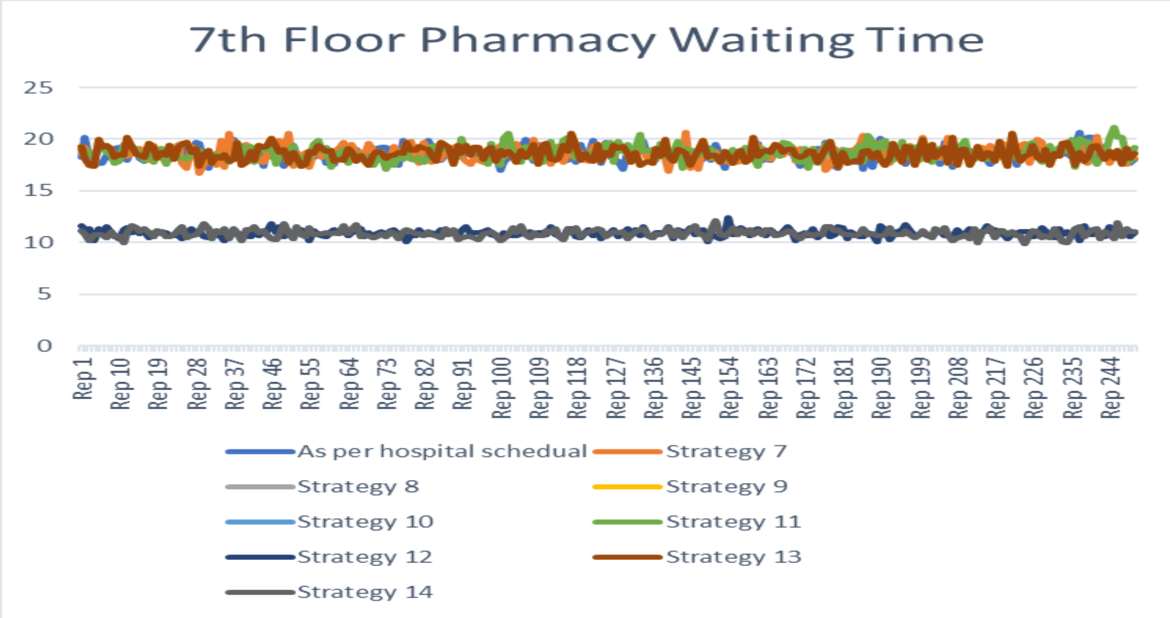


Figure 6:



Concisions

At the initial level, simulation was perceived with much cynicism. But the DES technique is technical in nature and very effective since it does not disturb any other structure of the concerned hospital. This research paper scientifically proves that combining a few very simple yet effective strategies would reduce the patient waiting time significantly. The research indicates that if the hospital keeps an additional part time employee, preferably a pharma student, the waiting time for the patients can be reduced by around 35% with one employee and 46% with two employees on 1st floor pharmacy store and 41% with one employee on 7th floor pharmacy store. Similarly, by adopting the fifth strategy of changing the staff level, the waiting time can be reduced approximately by 37% on 1st floor pharmacy store.

In case, the hospital management doesn't want to add new staff, it can still reduce the waiting time by 37% on 1st floor pharmacy store by adopting strategy-5.

Further, by combining the two strategies, the waiting time can be reduced significantly by 51% to 61% on 1st floor pharmacy store and 41% on 7th floor pharmacy store (See figure 7 and 8).

The suggested techniques are effective as they do not involve too many resources and doesn't disrupt the set workflow within the system. Health-care is a growing, varied and busy sector. DES technique is a scientific foundation enabling the policy-maker to acquire process-enhancement. It is hoped that this research paper will be useful in reducing the patients' waiting time by adding one or two staff members and changing the staff level. This also enhances the credibility and reputation of the concerned hospital. The suggested measures can also enhance the profits as the hospital can serve more patients in less time. Reduction in waiting time leads to high levels of satisfaction, resulting in the branding of the hospital. It is a win-win situation in a long run.

Figure 7: 1st floor pharmacy mean waiting time

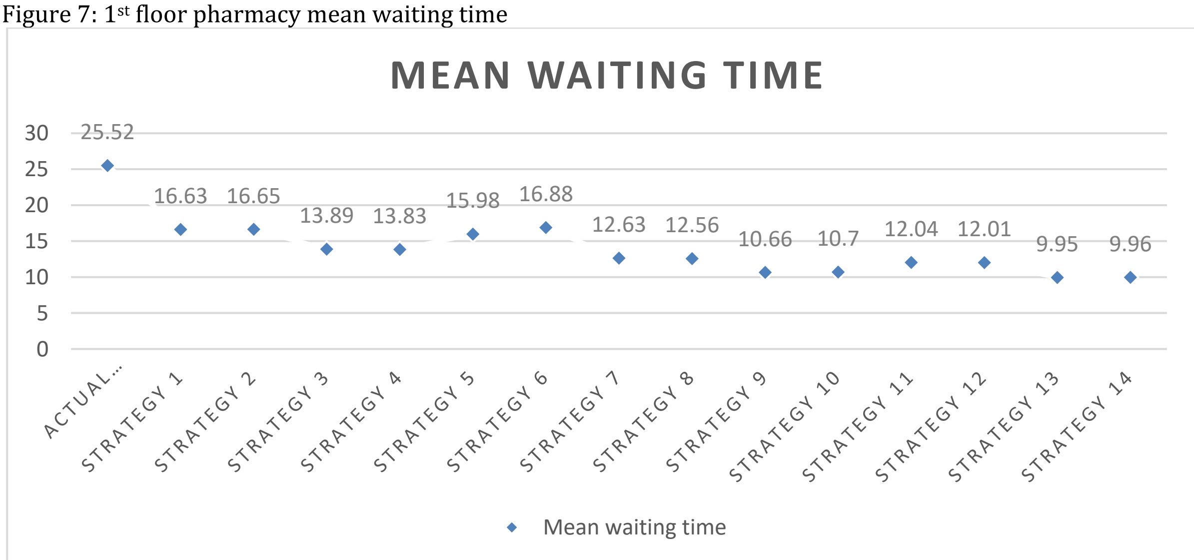
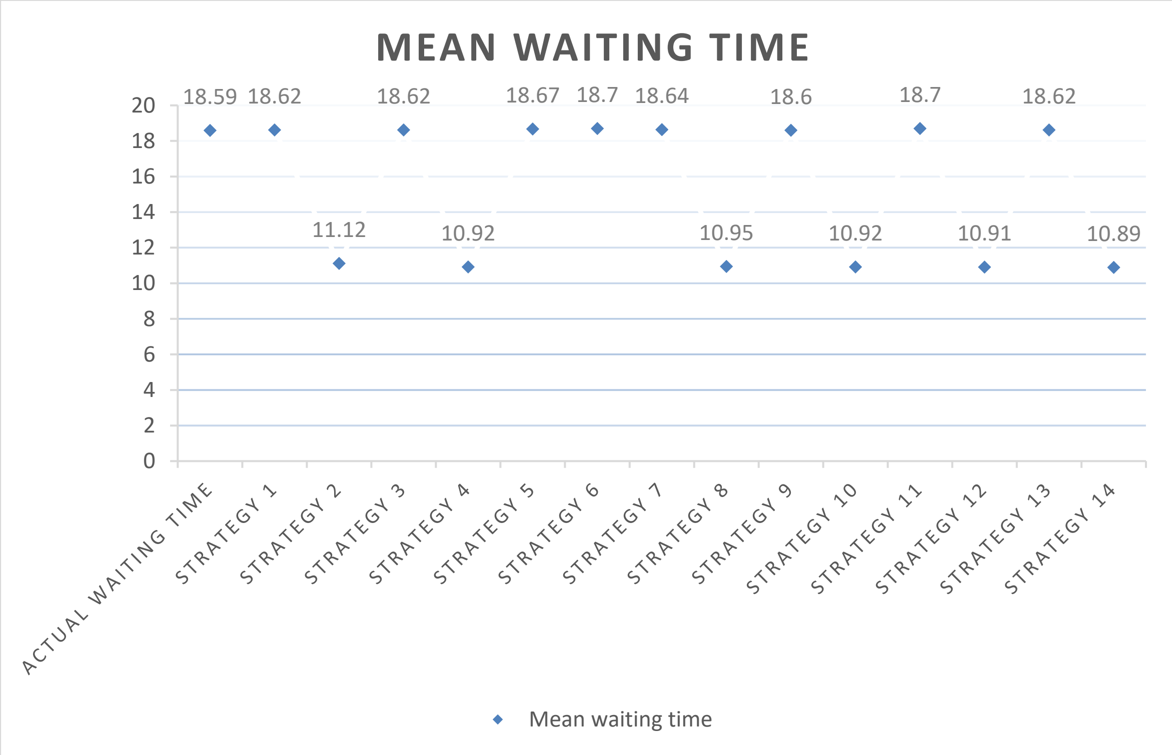


Figure 8: 7th floor pharmacy mean waiting time



Appendix:

Table 5: Actual man-power at pharmacy store

1st Floor Pharmay									
Time	A (8-4)	B (9-5)	C(9-5)	D(9-5)	E(12-8)	F(12-8)	G(12-8)	H(8-8)	Total
8	1								1
9	1								1
10	1	1							2
11	1	1	1						3
12		1	1	1					3
13		1	1	1					3
14				1	1				2
15				1	1				2
16						1	1		2
17						1	1		2
18					1	1	1		3
19					1	1	1		3
20								1	1
21								1	1
22								1	1
23								1	1
24								1	1
1								1	1
2								1	1
3								1	1
4								1	1
5								1	1
6								1	1
7								1	1

7th Floor Pharmay				
Time	I(8-4)	J(8-4)	K(12-8)	Total
8	1			1
9	1			1
10	1			1
11	1			1
12		1		1
13		1		1
14		1		1
15		1		1
16			1	1
17			1	1
18			1	1
19			1	1

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Table 6: Scheduling after adding one part time sales staff on 1st floor pharmacy - strategy 1

1st Floor Pharmay										
Time	A (8-4)	B (9-5)	C(9-5)	D(9-5)	E(12-8)	F(12-8)	G(12-8)	H(8-8)	Part time x	Total
8	1									1
9	1									1
10	1	1							1	3
11	1	1	1						1	4
12		1	1	1					1	4
13		1	1	1					1	4
14				1	1					2
15				1	1					2
16						1	1			2
17						1	1			2
18					1	1	1			3
19					1	1	1			3
20								1		1
21								1		1
22								1		1
23								1		1
24								1		1
1								1		1
2								1		1
3								1		1
4								1		1
5								1		1
6								1		1
7								1		1

7th Floor Pharmay				
Time	I(8-4)	J(8-4)	K(12-8)	Total
8	1			1
9	1			1
10	1			1
11	1			1
12		1		1
13		1		1
14		1		1
15		1		1
16			1	1
17			1	1
18			1	1
19			1	1

Table 7: Scheduling after adding one part time sales staff on 1st floor pharmacy and 7th floor pharmacy - strategy 2

1st Floor Pharmay										
Time	A (8-4)	B (9-5)	C(9-5)	D(9-5)	E(12-8)	F(12-8)	G(12-8)	H(8-8)	Part time x	Total
8	1									1
9	1									1
10	1	1							1	3
11	1	1	1						1	4
12		1	1	1					1	4
13		1	1	1					1	4
14				1	1					2
15				1	1					2
16						1	1			2
17						1	1			2
18					1	1	1			3
19					1	1	1			3
20								1		1
21								1		1
22								1		1
23								1		1
24								1		1
1								1		1
2								1		1
3								1		1
4								1		1
5								1		1
6								1		1
7								1		1

7th Floor Pharmay					
Time	I(8-4)	J(8-4)	K(12-8)	Part time y	Total
8	1				1
9	1				1
10	1			1	1
11	1			1	1
12		1		1	1
13		1		1	1
14		1			1
15		1			1
16			1		1
17			1		1
18			1		1
19			1		1

Table 8: Scheduling after adding two part time sales staffs on 1st floor pharmacy - strategy 3

1st Floor Pharmay											
Time	A (8-4)	B (9-5)	C(9-5)	D(9-5)	E(12-8)	F(12-8)	G(12-8)	H(8-8)	Part time x	Part time y	Total
8	1										1
9	1										1
10	1	1							1		3
11	1	1	1						1		4
12		1	1	1					1		4
13		1	1	1					1		4
14				1	1						2
15				1	1						2
16						1	1				2
17						1	1			1	3
18					1	1	1			1	4
19					1	1	1			1	4
20								1		1	2
21								1			1
22								1			1
23								1			1
24								1			1
1								1			1
2								1			1
3								1			1
4								1			1
5								1			1
6								1			1
7								1			1

7th Floor Pharmay				
Time	I(8-4)	J(8-4)	K(12-8)	Total
8	1			1
9	1			1
10	1			1
11	1			1
12		1		1
13		1		1
14		1		1
15		1		1
16			1	1
17			1	1
18			1	1
19			1	1

Table 9: Scheduling after adding two part time sales staffs on 1st floor pharmacy and one part time sales staff on 7th floor pharmacy - strategy 4

1st Floor Pharmay											
Time	A (8-4)	B (9-5)	C(9-5)	D(9-5)	E(12-8)	F(12-8)	G(12-8)	H(8-8)	Part time x	Part time y	Total
8	1										1
9	1										1
10	1	1							1		3
11	1	1	1						1		4
12		1	1	1					1		4
13		1	1	1					1		4
14				1	1						2
15				1	1						2
16						1	1				2
17						1	1			1	3
18					1	1	1			1	4
19					1	1	1			1	4
20								1		1	2
21								1			1
22								1			1
23								1			1
24								1			1
1								1			1
2								1			1
3								1			1
4								1			1
5								1			1
6								1			1
7								1			1

7th Floor Pharmay					
Time	I(8-4)	J(8-4)	K(12-8)	Part time z	Total
8	1				1
9	1				1
10	1			1	2
11	1			1	2
12		1		1	2
13		1		1	2
14		1			1
15		1			1
16			1		1
17			1		1
18			1		1
19			1		1

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Table 10: Changes in staffing levels – strategy 5

1st Floor Pharmay									
Time	A (8-4)	B (9-5)	C(9-5)	D(9-5)	E(12-8)	F(12-8)	G(12-8)	H(8-8)	Total
8	1								1
9	1	1							2
10	1	1	1						3
11	1	1	1	1					4
12	1	1	1	1					4
13		1	1	1					3
14				1	1				2
15				1	1				2
16						1	1		2
17					1	1	1		3
18					1	1	1		3
19					1	1	1		3
20								1	1
21								1	1
22								1	1
23								1	1
24								1	1
1								1	1
2								1	1
3								1	1
4								1	1
5								1	1
6								1	1
7								1	1

7th Floor Pharmay				
Time	I(8-4)	J(8-4)	K(12-8)	Total
8	1			1
9	1			1
10	1			1
11	1			1
12		1		1
13		1		1
14		1		1
15		1		1
16			1	1
17			1	1
18			1	1
19			1	1

Table 11: Changes in staffing levels – strategy 6

1st Floor Pharmay									
Time	A (8-4)	B (9-5)	C(10-6)	D(11-7)	E(12-8)	F(12-8)	G(12-8)	H(8-8)	Total
8	1								1
9	1								1
10	1	1	1						3
11	1	1	1						3
12	1	1	1	1					4
13		1	1	1					3
14		1		1	1				3
15				1	1				2
16						1	1		2
17			1		1	1	1		4
18				1	1	1	1		4
19					1	1	1		3
20								1	1
21								1	1
22								1	1
23								1	1
24								1	1
1								1	1
2								1	1
3								1	1
4								1	1
5								1	1
6								1	1
7								1	1

7th Floor Pharmay				
Time	I(8-4)	J(8-4)	K(12-8)	Total
8	1			1
9	1			1
10	1			1
11	1			1
12		1		1
13		1		1
14		1		1
15		1		1
16			1	1
17			1	1
18			1	1
19			1	1

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Table 12: Scheduling after adding one part time sales staff into strategy 5– strategy 7

1st Floor Pharmay										
Time	A (8-4)	B (9-5)	C(9-5)	D(9-5)	E(12-8)	F(12-8)	G(12-8)	H(8-8)	Part time x	Total
8	1									1
9	1	1								2
10	1	1	1						1	4
11	1	1	1	1					1	5
12	1	1	1	1					1	5
13		1	1	1					1	4
14				1	1					2
15				1	1					2
16						1	1			2
17					1	1	1			3
18					1	1	1			3
19					1	1	1			3
20								1		1
21								1		1
22								1		1
23								1		1
24								1		1
1								1		1
2								1		1
3								1		1
4								1		1
5								1		1
6								1		1
7								1		1

7th Floor Pharmay				
Time	I(8-4)	J(8-4)	K(12-8)	Total
8	1			1
9	1			1
10	1			1
11	1			1
12		1		1
13		1		1
14		1		1
15		1		1
16			1	1
17			1	1
18			1	1
19			1	1

Table 13: Scheduling after adding two part time sales staffs into strategy 5– strategy 8

1st Floor Pharmay										
Time	A (8-4)	B (9-5)	C(9-5)	D(9-5)	E(12-8)	F(12-8)	G(12-8)	H(8-8)	Part time x	Total
8	1									1
9	1	1								2
10	1	1	1						1	4
11	1	1	1	1					1	5
12	1	1	1	1					1	5
13		1	1	1					1	4
14				1	1					2
15				1	1					2
16						1	1			2
17					1	1	1			3
18					1	1	1			3
19					1	1	1			3
20								1		1
21								1		1
22								1		1
23								1		1
24								1		1
1								1		1
2								1		1
3								1		1
4								1		1
5								1		1
6								1		1
7								1		1

7th Floor Pharmay					
Time	I(8-4)	J(8-4)	K(12-8)	Part time y	Total
8	1				1
9	1				1
10	1			1	2
11	1			1	2
12		1		1	2
13		1		1	2
14		1			1
15		1			1
16			1		1
17			1		1
18			1		1
19			1		1

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Table 14: Scheduling after adding two part time sales staffs into strategy 5– strategy 9

1st Floor Pharmay

Time	A (8-4)	B (9-5)	C(9-5)	D(9-5)	E(12-8)	F(12-8)	G(12-8)	H(8-8)	Part time X	Part time Y	Total
8	1										1
9	1	1									2
10	1	1	1						1		4
11	1	1	1	1					1		5
12	1	1	1	1					1		5
13		1	1	1					1		4
14				1	1						2
15				1	1						2
16						1	1				2
17					1	1	1			1	4
18					1	1	1			1	4
19					1	1	1			1	4
20								1		1	2
21								1			1
22								1			1
23								1			1
24								1			1
1								1			1
2								1			1
3								1			1
4								1			1
5								1			1
6								1			1
7								1			1

7th Floor Pharmay

Time	I(8-4)	J(8-4)	K(12-8)	Total
8	1			1
9	1			1
10	1			1
11	1			1
12		1		1
13		1		1
14		1		1
15		1		1
16			1	1
17			1	1
18			1	1
19			1	1

Table 15: Scheduling after adding three part time sales staffs into strategy 5– strategy 10

1st Floor Pharmay

Time	A (8-4)	B (9-5)	C(9-5)	D(9-5)	E(12-8)	F(12-8)	G(12-8)	H(8-8)	Part time X	Part time Y	Total
8	1										1
9	1	1									2
10	1	1	1						1		4
11	1	1	1	1					1		5
12	1	1	1	1					1		5
13		1	1	1					1		4
14				1	1						2
15				1	1						2
16						1	1				2
17					1	1	1			1	4
18					1	1	1			1	4
19					1	1	1			1	4
20								1		1	2
21								1			1
22								1			1
23								1			1
24								1			1
1								1			1
2								1			1
3								1			1
4								1			1
5								1			1
6								1			1
7								1			1

7th Floor Pharmay

Time	I(8-4)	J(8-4)	K(12-8)	Part time Z	Total
8	1				1
9	1				1
10	1			1	2
11	1			1	2
12		1		1	2
13		1		1	2
14		1			1
15		1			1
16			1		1
17			1		1
18			1		1
19			1		1

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Table 16: Scheduling after adding one part time sales staff into strategy 6– strategy 11

1st Floor Pharmay

Time	A (8-4)	B (9-5)	C(10-6)	D(11-7)	E(12-8)	F(12-8)	G(12-8)	H(8-8)	Part time X	Total
8	1									1
9	1									1
10	1	1	1						1	4
11	1	1	1						1	4
12	1	1	1	1					1	5
13		1	1	1					1	4
14		1		1	1					3
15				1	1					2
16						1	1			2
17			1		1	1	1			4
18				1	1	1	1			4
19					1	1	1			3
20								1		1
21								1		1
22								1		1
23								1		1
24								1		1
1								1		1
2								1		1
3								1		1
4								1		1
5								1		1
6								1		1
7								1		1

7th Floor Pharmay

Time	I(8-4)	J(8-4)	K(12-8)	Total
8	1			1
9	1			1
10	1			1
11	1			1
12		1		1
13		1		1
14		1		1
15		1		1
16			1	1
17			1	1
18			1	1
19			1	1

Table 17: Scheduling after adding two part time sales staffs into strategy 6– strategy 12

1st Floor Pharmay

Time	A (8-4)	B (9-5)	C(10-6)	D(11-7)	E(12-8)	F(12-8)	G(12-8)	H(8-8)	Part time X	Total
8	1									1
9	1									1
10	1	1	1						1	4
11	1	1	1						1	4
12	1	1	1	1					1	5
13		1	1	1					1	4
14		1		1	1					3
15				1	1					2
16						1	1			2
17			1		1	1	1			4
18				1	1	1	1			4
19					1	1	1			3
20								1		1
21								1		1
22								1		1
23								1		1
24								1		1
1								1		1
2								1		1
3								1		1
4								1		1
5								1		1
6								1		1
7								1		1

7th Floor Pharmay

Time	I(8-4)	J(8-4)	K(12-8)	Part time Y	Total
8	1				1
9	1				1
10	1			1	2
11	1			1	2
12		1		1	2
13		1		1	2
14		1			1
15		1			1
16			1		1
17			1		1
18			1		1
19			1		1

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Table 18: Scheduling after adding two part time sales staffs into strategy 6– strategy 13

1st Floor Pharmay											
Time	A (8-4)	B (9-5)	C(10-6)	D(11-7)	E(12-8)	F(12-8)	G(12-8)	H(8-8)	Part time X	Part time Y	Total
8	1										1
9	1										1
10	1	1	1						1		4
11	1	1	1						1		4
12	1	1	1	1					1		5
13		1	1	1					1		4
14		1		1	1						3
15				1	1						2
16						1	1				2
17			1		1	1	1			1	5
18				1	1	1	1			1	5
19					1	1	1			1	4
20								1		1	2
21								1			1
22								1			1
23								1			1
24								1			1
1								1			1
2								1			1
3								1			1
4								1			1
5								1			1
6								1			1
7								1			1

7th Floor Pharmay				
Time	I(8-4)	J(8-4)	K(12-8)	Total
8	1			1
9	1			1
10	1			1
11	1			1
12		1		1
13		1		1
14		1		1
15		1		1
16			1	1
17			1	1
18			1	1
19			1	1

Table 19: Scheduling after adding three part time sales staffs into strategy 6– strategy 14

1st Floor Pharmay											
Time	A (8-4)	B (9-5)	C(10-6)	D(11-7)	E(12-8)	F(12-8)	G(12-8)	H(8-8)	Part time X	Part time Y	Total
8	1										1
9	1										1
10	1	1	1						1		4
11	1	1	1						1		4
12	1	1	1	1					1		5
13		1	1	1					1		4
14		1		1	1						3
15				1	1						2
16						1	1				2
17			1		1	1	1			1	5
18				1	1	1	1			1	5
19					1	1	1			1	4
20								1		1	2
21								1			1
22								1			1
23								1			1
24								1			1
1								1			1
2								1			1
3								1			1
4								1			1
5								1			1
6								1			1
7								1			1

7th Floor Pharmay					
Time	I(8-4)	J(8-4)	K(12-8)	Part time Z	Total
8	1				1
9	1				1
10	1			1	2
11	1			1	2
12		1		1	2
13		1		1	2
14		1			1
15		1			1
16			1		1
17			1		1
18			1		1
19			1		1

Table 20: Mean waiting time of all strategy, minutes (95% CI)

Strategy	1st floor pharmacy	7th floor pharmacy
Actual Waiting Time	25.52 (25.40 to 25.64)	18.59 (18.48 to 18.70)
Strategy 1	16.63 (16.52 to 16.63)	18.62 (18.51 to 18.73)
Strategy 2	16.65 (16.55 to 16.65)	11.12 (11.03 to 11.21)
Strategy 3	13.89 (13.80 to 13.98)	18.62 (18.51 to 18.73)
Strategy 4	13.83 (13.73 to 13.93)	10.92 (10.82 to 10.92)
Strategy 5	15.98 (15.85 to 16.11)	18.67 (18.53 to 18.81)
Strategy 6	16.88 (16.73 to 17.03)	18.70 (18.55 to 18.85)
Strategy 7	12.63 (12.52 to 12.74)	18.64 (18.55 to 18.73)
Strategy 8	12.56 (12.44 to 12.68)	10.95 (10.84 to 11.06)
Strategy 9	10.66 (10.57 to 10.75)	18.60 (18.52 to 18.68)
Strategy 10	10.70 (10.60 to 10.80)	10.92 (10.81 to 11.03)

Strategy 11	12.04 (11.94 to 12.14)	18.70 (18.61 to 18.79)
Strategy 12	12.01 (11.89 to 12.13)	10.91 (10.81 to 11.01)
Strategy 13	9.95 (9.84 to 10.06)	18.62 (18.53 to 18.71)
Strategy 14	9.96 (9.86 to 10.06)	10.89 (10.78 to 11)

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