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ANALYSIS OF OUTPATIENT WAITING TIME USING DES

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Abstract

The current paper strives to understand how a Discrete Event Simulation (DES) helps in improving efficiency by reducing waiting time in hospital pharmacy outpatients.

Having created a model and established its face validity, the paper tests scenarios to estimate the likely impact of changes in staffing levels. The basic purpose of simulation model is to reduce the patients' waiting time and enhance the quality of services.

To achieve the main objectives of research, primary data was collected from a private hospital in Ahmedabad over a three-month period from June-2021 to August-2021. Discrete Event Simulation (DES) technique was used to draw the inferences.

The study found that by introducing an additional sales staff/s; 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 complexity of the service system of the hospital pharmacies is majorly because of the diverse orders (prescriptions) from the customers, a wide range of staff with groupings of roles. The incorporation of advanced technological solutions for improving the precision and swiftness of drug dispensing is also one of the reasons that the service system gets more complex in the initial stage. For each prescribed item, the prescription is printed, a bill is generated of available or similar medicine, the bill amount is informed to the patients and if the patient agrees to buy the medicine, then the bill is printed, and then the relevant product is selected and checked, the correct number of dose units is counted and repackaged if necessary, and the product is labelled. The completed prescription is reverified by a pharmacist, who also confirms if a valid dosage regimen has been prescribed before handing out to the relevant 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 procedures of the dispensaries can be modified in many different ways to increase the efficiency. By alteration of workflows, introduction of prioritization systems, and change in the staffing patterns, this could be incorporated. However, it is not easy 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. If it does not go well, the reversal of the unsuccessful changes could be difficult and is demotivating for the staff.

Computer Simulation Modelling is one of the best ways to avoid many potential problems. The possible effect of changes to the process of the dispensaries' could be explored without risk disruption. Also, a variety of options can be explored under identical "experimental" conditions, 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 can lead to a greater understanding of the system under study. Computer simulation in healthcare is widely reported in the literature [15,22,33]. However, while there have been several studies using simulation to study pharmacy systems [7,20,21,27,29], the only one to have specifically examined the hospital pharmacy dispensary was published in 1974 [20]. 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.

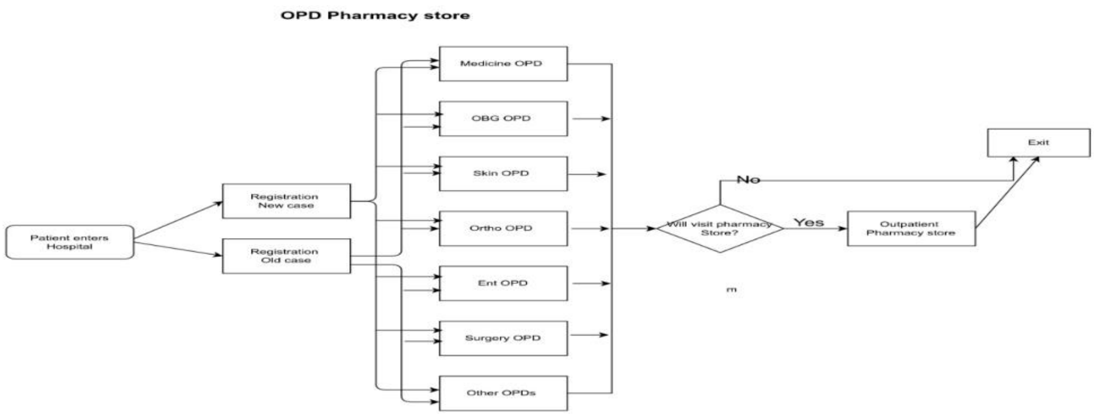
LITERATURE REVIEW

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 a single outpatient pharmacy located within a tertiary hospital in Ahmedabad. The pharmacy operates between 8 am and 8 pm on weekdays and between 8 am and 4 pm on Saturdays. At the time of the study, the outlet was staffed with up to 7 pharmacists and 4 runners/ assistants who worked for 8 hours shifts on weekdays and Saturdays.
Outpatients take a treatment in any one of thirteen OPDs before going to the pharmacy store. The doctor prescribes medicine if he feels the need, which is also inserted into the computer system, which can be seen by the pharmacist at the pharmacy store. The patient who has been prescribed the medicine stands in the line of the pharmacy store with his case paper. When his number comes, he gives his case paper to the pharmacist. The pharmacist enters the patient's case number into the computer system and prints the prescription of the drug. He indicates whether the medicine is available or not and how much it is worth if available. If the patient agrees, he will be billed and a prescription is given to the runner to extract the medicine. Runner gives the medicines to the pharmacist and pharmacist checks the medicine and label on it. Upon completing the verification, he will explain to the patient the purpose, dosage frequency of each prescribed medication as well as the possible side effects and precautions to observe while on specific medications. He collects the money and gives the medicine to the outpatient. The entire process is served on a first-come-first-serve basis.

Figure 1: Process overview of the outpatient pharmacy.



MODEL DEVELOPMENT

After mapping out the processes within the pharmacy as illustrated in Figure 1, a DES model representing the workflow processes in outpatient pharmacy was developed using a commercial simulation software (Arena Professional Edition v14). This model used system characteristics of pharmacy for simulating the series of activities taking place between the registrations of the cases and the process of dispensing. These characteristics included patients' arrival and existing manpower allocation schedule. The consolidated process parameters that served as DES model input were based on either 3-month electronically archived data or data collected via a 2-week time motion study.

Analyzing the outpatient pharmacy's 3-month retrospective patient load data, it was observed that the average arrival was 1198 patients per day and the medicines sold at the pharmacy store was 497 per day. 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. Table 1 shows percentage of different types of OPDs' outpatient visit pharmacy store to buy medicines.

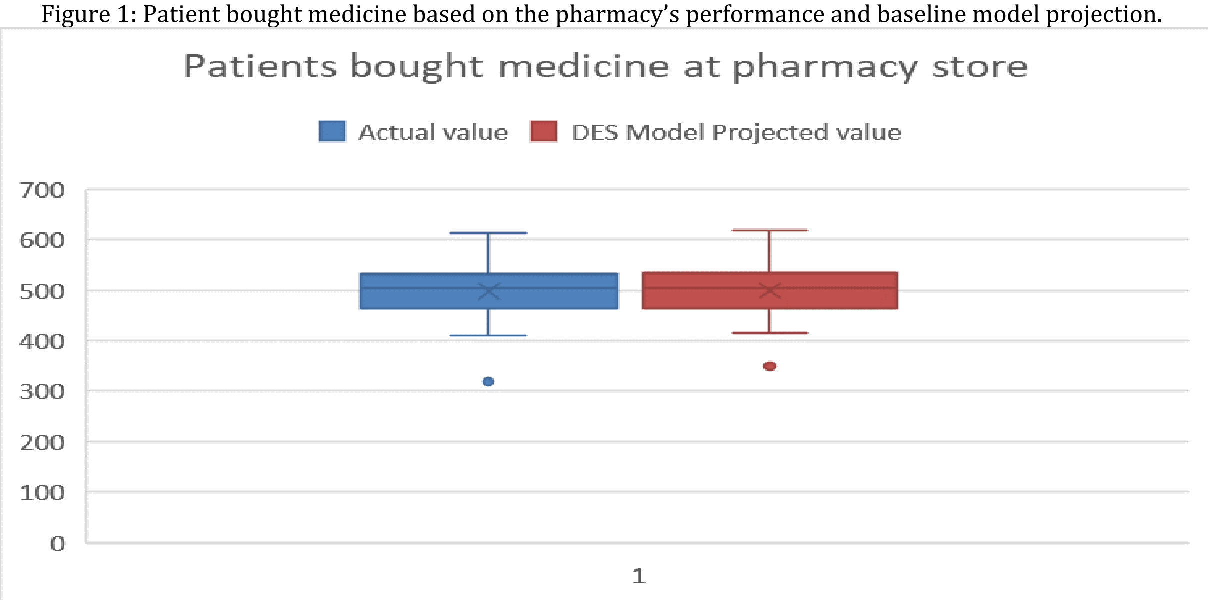
Table 1: Percentage of outpatients to buy medicine from different OPDs.

OPD	Buy medicine %
Medicine	25.31
OBG	17.34
Skin	43.06
Orthopedic	39.52
Surgery	15.08
ENT	26.46
Others	22.26

MODEL VALIDATION

This simulation model was run for 500 replications. For model validation purpose, a 95% confidence interval was calculated. Observed mean waiting time in the real-life was 30.6 minutes (95% confidence interval 28.3 to 32.9 minutes) and comparable to those estimated by the baseline model: 29.1 minutes (95% confidence interval 28.93 to 29.27 minutes). Second, the actual number of patients who bought medicine was 497 and as per the model, bills generated from the store were 499 (see figure 1).

Figure 1: Patient bought medicine based on the pharmacy's performance and baseline model projection.



'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 we introduce an additional part time sales staff/s; preferably pharma-student/s (at the payment of a small stipend) in peak-hours: 10 am to 2 pm (denoted by strategies 1 and 2, see table 6), we can open one/two extra windows to reduce waiting time of outpatient. The simulation output was compared with that of the baseline model.

(b) Changes in staffing levels

It was claimed that the reduction in the patient waiting time could be made possible if the manpower can better match the arrival pattern of the patients. Many new manpower scheduling strategies were tried, tested and derived. Of course, the derivation process was done on a trial and error basis where the modifications were made in the earlier processes as required. Overall, three manpower scheduling techniques were developed and their respective effect on the patient cycle time and manpower requirements were projected with the DES model. (Tables 7 to 9)

(c) Multilevel staffing strategy

Changing the staffing level can reduce the time and if we add sales staff/s in the peak time then patient waiting time can be further reduced. We can add sales staff/s in three new manpower scheduling strategies (see table 10 to 12). This derivation was done on trial and error basis. The simulation output was compared with that of the baseline model and changing the staffing level strategy.

RESULT

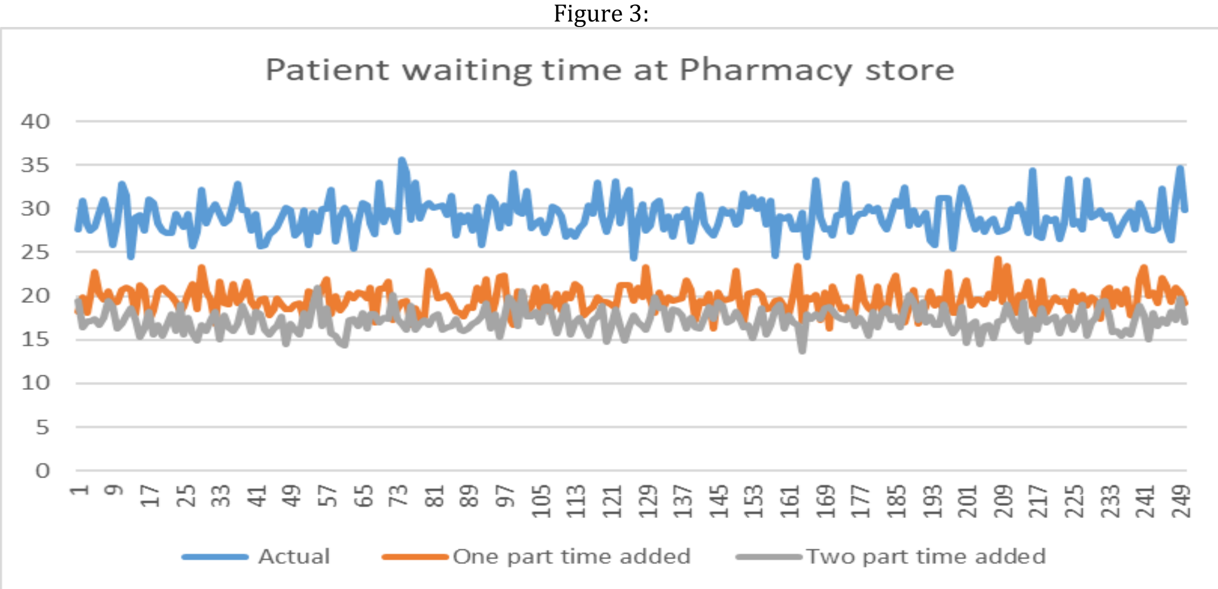
(a) Adding an additional part time sales staff/s

We found that, as expected, the addition of extra staff improved the current system and decreased mean waiting time. When we introduce one part time sales staff, mean waiting time: 19.57 minutes (95% confidence interval 19.44 to 19.70 minutes) and two sale staffs, mean waiting time: 17.30 minutes (95% confidence interval 17.19 to 17.41 minutes). (see table 2, figure 3). Hence it is proven that this technique highly reduced the waiting time of the patients.

Table 2:

Strategy	Mean waiting time, minutes (95% CI)
Actual Waiting Time	30.6 (28.3 to 23.9)
Waiting Time after adding 1-part timer (Strategy 1)	19.57 (19.44 to 19.70)
Waiting Time after adding 2-part timer (Strategy 2)	17.30 (17.19 to 17.41)

Figure 3:



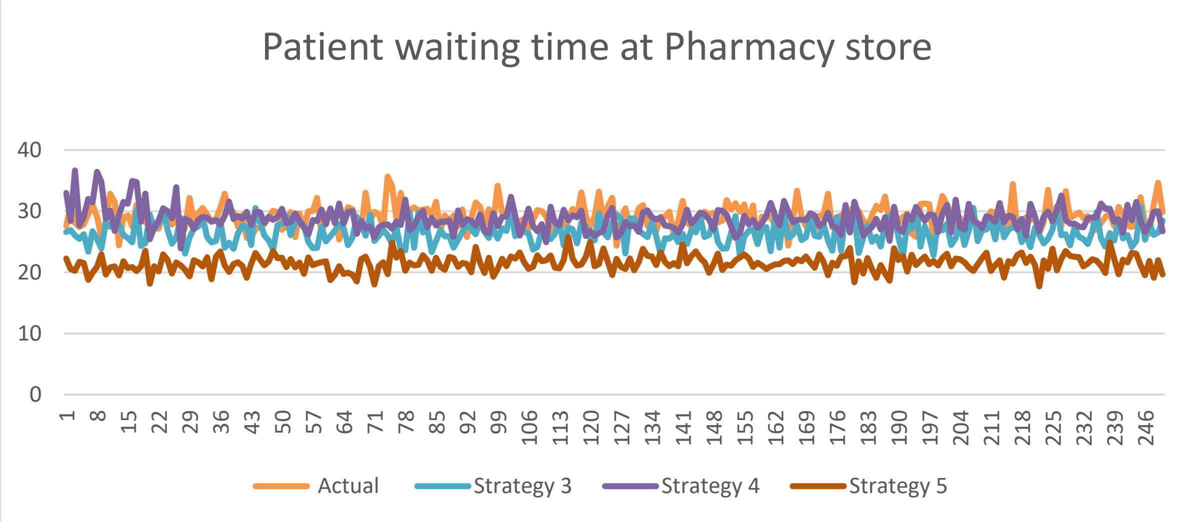
(b) Changes in staffing levels

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 three new manpower scheduling strategies (denoted by strategies 3, 4 and 5), decrease in mean waiting time. When we introduce strategy 3, mean waiting time: 26.59 minutes (95% confidence interval 26.36 to 26.82 minutes), strategy 4, mean waiting time: 28.57 minutes (95% confidence interval 28.38 to 28.76 minutes) and strategy 5, mean waiting time: 21.48 minutes (95% confidence interval 21.36 to 21.64 minutes). (See table 3 and figure 4)

Table 3:

Strategy	Mean waiting time, minutes (95% CI)
Actual Waiting Time	30.6 (28.3 to 23.9)
Strategy 3	26.59 (26.36 to 26.82)
Strategy 4	28.57 (28.38 to 28.76)
Strategy 5	21.64 (21.36 to 21.64)

Figure 4:



(c) Multilevel staffing strategy

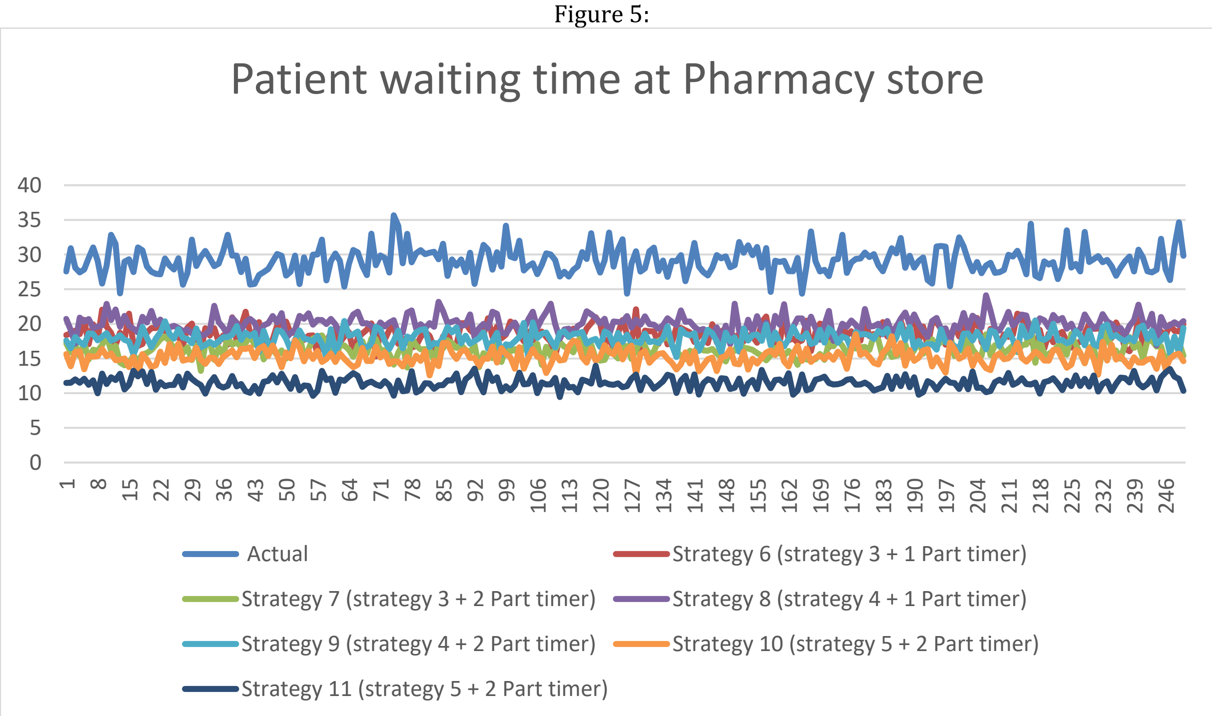
We found that, multilevel staffing strategy (denoted by strategies 6 to 11), highly decrease in mean waiting time.

When we introduce strategy 6: mean waiting time: 18.50 minutes (95% confidence interval 18.37 to 18.67 minutes), strategy 7: mean waiting time: 16.33 minutes (95% confidence interval 16.19 to 16.47 minutes), strategy 8: mean waiting time: 20.01 minutes (95% confidence interval 19.86 to 20.16 minutes), strategy 9: mean waiting time: 17.94 minutes (95% confidence interval 17.81 to 18.07 minutes), strategy 10: mean waiting time: 15.23 minutes (95% confidence interval 15.09 to 15.37 minutes), and strategy 11: mean waiting time: 11.48 minutes (95% confidence interval 11.37 to 11.59 minutes). (See table 4 and figure 5)

Table 4:

Strategy	Mean waiting time, minutes (95% CI)
Actual Waiting Time	30.6 (28.3 to 23.9)
Strategy 6 (strategy 3 + 1 Part timer)	18.50 (18.37 to 18.67)
Strategy 7 (strategy 3 + 2 Part timer)	16.33 (16.19 to 16.47)
Strategy 8 (strategy 4 + 1 Part timer)	20.01 (19.86 to 20.16)
Strategy 9 (strategy 4 + 2 Part timer)	17.94 (17.81 to 18.07)
Strategy 10 (strategy 5 + 1 Part timer)	15.23 (15.09 to 15.37)
Strategy 11 (strategy 5 + 2 Part timer)	11.48 (11.37 to 11.59)

Figure 5:



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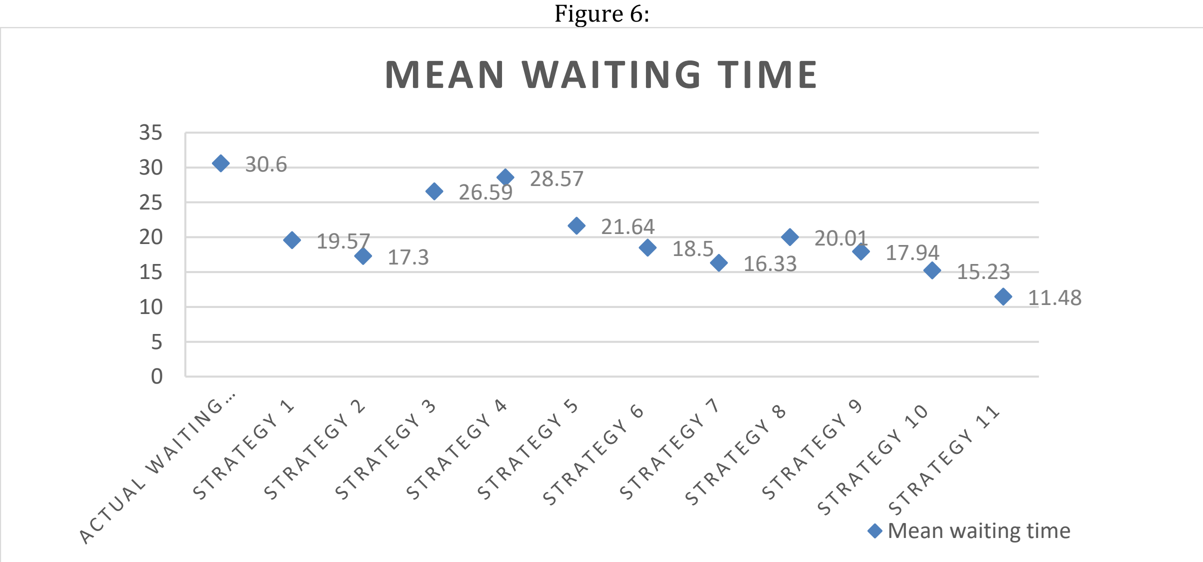
CONCISIONS

Initially, simulation was perceived with a lot of skepticism. However, the DES technique is a bit technical in nature but is extremely effective as it does not disturb any other structure of the concerned hospital. In this context, the current research paper scientifically proves with evidence that combining a couple of very simple yet effective strategies would reduce the patient waiting time considerably. 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 36% with one employee and 43% with two employees. Similarly, by adopting the second strategy of changing the staff level, the waiting time can be reduced approximately by 7% to 30%.
In case, the hospital management doesn't want to add new staff, it can still reduce the waiting time by 30% by adopting strategy-5.
Further, by combining the two strategies, the waiting time can be reduced significantly by 2/3rd. (See figure 6)
The suggested techniques are very effective because it does not involve too many resources and also doesn't disrupt the set workflow within the system. Health-care is a dynamic and busy sector. DES technique is an excellent scientific foundation which enables the policy-maker to acquire process-enhancement. The researchers are hopeful that the current research paper will be useful in reducing the patients' waiting time by adding one or two staff members and changing the staff level. This is also likely to enhance the credibility and reputation of the concerned hospital. Besides, the suggested measures can enhance the profits as the hospital can serve more patients in less time. The waiting time of the patients is reduced leading to high levels of satisfaction. This would result in to the branding of the hospital. It is a win-win situation in a long run.

Figure 6:



Appendix:

Table 5: Actual man-power at pharmacy store

	A (8 – 4)	B (9 – 5)	C (9 – 5)	D (10 – 6)	E (10 – 6)	F (12 – 8)	G (12 – 8)	TOTAL service window
8	1							1
8.5	1							1
9.0	1	1	1					3
9.5	1	1	1					3
10.0	1	1	1	1	1			5
10.5	1	1	1	1	1			5
11.0	1	1	1	1	1			5
11.5	1	1	1	1	1			5
12.0	1	1	1	1	1			5
12.5	1	1	1	1	1			5
1.0			1	1	1			3
1.5					1	1	1	3
2.0	1	1				1	1	4
2.5		1	1			1	1	4
3.0		1	1			1	1	4
3.5				1	1	1	1	4
4.0				1	1	1	1	4
4.5				1	1	1	1	4
5.0						1	1	2
5.5						1	1	2
6.0						1		1
6.5						1		1
7.0							1	1
7.5							1	1

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Table 4: Scheduling after adding part time sales staff/s

	A	B	C	D	E	F	G	Part-time X	Part-time Y	TOTAL service window
8	1									1
8.5	1									1
9	1	1	1							3
9.5	1	1	1							3
10	1	1	1	1	1			1	1	7
10.5	1	1	1	1	1			1	1	7
11	1	1	1	1	1			1	1	7
11.5	1	1	1	1	1			1	1	7
12	1	1	1	1	1			1	1	7
12.5	1	1	1	1	1			1	1	7
1			1	1	1			1	1	5
1.5					1	1	1	1	1	5
2	1	1				1	1			4
2.5		1	1			1	1			4
3		1	1			1	1			4
3.5				1	1	1	1			4
4				1	1	1	1			4
4.5				1	1	1	1			4
5						1	1			2
5.5						1	1			2
6						1				1
6.5						1				1
7							1			1
7.5							1			1

Table 5: Changes in staffing levels – strategy 3

	A (8 – 4)	B (9 – 5)	C (9 – 5)	D (10 – 6)	E (10 – 6)	F (10 – 6)	G (12 – 8)	TOTAL service window
8	1							1
8.5	1							1
9	1	1	1					3
9.5	1	1	1					3
10	1	1	1	1	1	1		6
10.5	1	1	1	1	1	1		6
11	1	1	1	1	1	1		6
11.5	1	1	1	1	1	1		6
12	1	1	1	1	1	1		6
12.5	1	1	1	1	1	1		6
1			1	1	1	1		4
1.5				1	1	1	1	4
2	1	1					1	3
2.5		1	1				1	3
3		1	1	1				3
3.5				1	1	1		3
4					1	1	1	3
4.5					1	1	1	3
5							1	1
5.5							1	1
6							1	1
6.5							1	1
7							1	1
7.5							1	1

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Table 6: Changes in staffing levels – strategy 5

	A (8 – 4)	B (9 – 5)	C (9 – 5)	D (10 – 6)	E (10 – 6)	F (10 – 6)	G (12 – 8)	TOTAL service window
8	1							1
8.5	1							1
9	1	1	1					3
9.5	1	1	1					3
10	1	1	1	1	1	1		6
10.5	1	1	1	1	1	1		6
11	1	1	1	1	1	1		6
11.5	1	1	1	1	1	1		6
12	1	1	1	1	1	1	1	7
12.5	1	1	1	1	1	1	1	7
1			1	1	1	1	1	5
1.5				1	1	1	1	4
2	1	1			1		1	4
2.5		1	1	1				3
3		1	1	1				3
3.5				1	1	1		3
4	1				1	1		3
4.5						1		1
5							1	1
5.5							1	1
6							1	1
6.5							1	1
7							1	1
7.5							1	1

Table 7: Changes in staffing levels – strategy 6

	A (8 – 4)	B (9 – 5)	C (9 – 5)	D (10 – 6)	E (10 – 6)	F (10 – 6)	G (12 – 8)	TOTAL service window
8	1							1
8.5	1							1
9	1	1	1					3
9.5	1	1	1					3
10	1	1	1	1	1	1		6
10.5	1	1	1	1	1	1		6
11	1	1	1	1	1	1		6
11.5	1	1	1	1	1	1		6
12	1	1	1	1	1	1	1	7
12.5	1	1	1	1	1	1	1	7
1			1	1	1	1	1	5
1.5		1		1	1	1	1	5
2	1	1		1	1	1	1	6
2.5	1	1	1					3
3			1	1				2
3.5				1	1			2
4					1	1		2
4.5						1		1
5							1	1
5.5							1	1
6							1	1
6.5							1	1
7							1	1
7.5							1	1

Table 8: Scheduling after adding part time sales staff/s into strategy 5

	A (8 - 4)	B (9 - 5)	C (9 - 5)	D (10 - 6)	E (10 - 6)	F (10 - 6)	G (12 - 8)	Part-time X	Part-time Y	TOTAL service window
8	1									1
8.5	1									1
9	1	1	1							3
9.5	1	1	1							3
10	1	1	1	1	1	1		1	1	8
10.5	1	1	1	1	1	1		1	1	8
11	1	1	1	1	1	1		1	1	8
11.5	1	1	1	1	1	1		1	1	8
12	1	1	1	1	1	1		1	1	8
12.5	1	1	1	1	1	1		1	1	8
1			1	1	1	1		1	1	6
1.5				1	1	1	1	1	1	6
2	1	1					1			3
2.5		1	1				1			3
3		1	1	1						3
3.5				1	1	1				3
4					1	1	1			3
4.5					1	1	1			3
5							1			1
5.5							1			1
6							1			1
6.5							1			1
7							1			1
7.5							1			1

Table 9: Scheduling after adding part time sales staff/s into strategy 6

	A (8 - 4)	B (9 - 5)	C (9 - 5)	D (10 - 6)	E (10 - 6)	F (10 - 6)	G (12 - 8)	Part-time X	Part-time Y	TOTAL service window
8	1									1
8.5	1									1
9	1	1	1							3
9.5	1	1	1							3
10	1	1	1	1	1	1		1	1	8
10.5	1	1	1	1	1	1		1	1	8
11	1	1	1	1	1	1		1	1	8
11.5	1	1	1	1	1	1		1	1	8
12	1	1	1	1	1	1	1	1	1	9
12.5	1	1	1	1	1	1	1	1	1	9
1			1	1	1	1	1	1	1	7
1.5				1	1	1	1	1	1	6
2	1	1			1		1			4
2.5		1	1	1						3
3		1	1	1						3
3.5				1	1	1				3
4	1				1	1				3
4.5						1				1
5							1			1
5.5							1			1
6							1			1
6.5							1			1
7							1			1
7.5							1			1

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Table 10: Scheduling after adding part time sales staff/s into strategy 7

	A (8 – 4)	B (9 – 5)	C (9 – 5)	D (10 – 6)	E (10 – 6)	F (10 – 6)	G (12 – 8)	Part-time X	Part-time Y	TOTAL service window
8	1									1
8.5	1									1
9	1	1	1							3
9.5	1	1	1							3
10	1	1	1	1	1	1		1	1	8
10.5	1	1	1	1	1	1		1	1	8
11	1	1	1	1	1	1		1	1	8
11.5	1	1	1	1	1	1		1	1	8
12	1	1	1	1	1	1	1	1	1	9
12.5	1	1	1	1	1	1	1	1	1	9
1			1	1	1	1	1	1	1	7
1.5		1		1	1	1	1	1	1	7
2	1	1		1	1	1	1			6
2.5	1	1	1							3
3			1	1						2
3.5				1	1					2
4					1	1				2
4.5						1				1
5							1			1
5.5							1			1
6							1			1
6.5							1			1
7							1			1
7.5							1			1

Table 13: Waiting time of all strategy

Strategy	Mean waiting time, minutes (95% CI)
Actual Waiting Time	30.6 (28.3 to 23.9)
Strategy 1	19.57 (19.44 to 19.70)
Strategy 2	17.30 (17.19 to 17.41)
Strategy 3	26.59 (26.36 to 26.82)
Strategy 4	28.57 (28.38 to 28.76)
Strategy 5	21.64 (21.36 to 21.64)
Strategy 6	18.50 (18.37 to 18.67)
Strategy 7	16.33 (16.19 to 16.47)
Strategy 8	20.01 (19.86 to 20.16)
Strategy 9	17.94 (17.81 to 18.07)
Strategy 10	15.23 (15.09 to 15.37)
Strategy 11	11.48 (11.37 to 11.59)

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