SERVICE TIME REDUCTION OF A SELECTED HOSPITAL THROUGH THE APPLICATION OF LEAN TOOLS

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Abstract. *Hospitals of Bangladesh are facing lots of problems due to the inefficient management of the resources. To overcome the problem, a variety of process improvement methodologies have been proposed. Lean tools are one of such methods. As the concept of lean is pretty new for the health care, the improvements due to the application of lean tools are not yet fully recognized. In this study, the lean methodology is used to assess the performance of a selected hospital in Bangladesh. The main objective of the study is to identify various wastes that occur in the healthcare system and to reduce if not eliminate them. Additionally, it tries to find out areas of improvement in the system and proposes some improvement strategies. In this concern, both outdoor and indoor systems were infiltrated and relevant data were collected. Problems were categorized and mitigated using appropriate lean tools. The results of the current state simulation run were used to suggest two improved alternative future state models which significantly reduced the waiting time from 376.05 minutes to 231.6 minutes, hence the total process time from 419 minutes to 276 minutes and increased the value added time quotient from 4.77% to 7.25%.*

Keywords: *Service time; Health care facility; VSM; Simulation.*
JEL Classification: *L31*

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1. Introduction

Prioritization of resources is a vital concern for healthcare organizations. The sector has to ensure high quality patient care, prevention of infections, and maintenance of hospital security and safety of patients with the economical use of their resources. Two of the most important issues that healthcare organizations around the world face today are financial challenges (hospital productivity) and patient satisfaction [1]. The hospitals of Bangladesh have been under pressure from politicians, employees, and the public to reduce costs while still improving quality. This development pressures healthcare organizations to achieve the same level of quality of care, but with fewer resources. The second main challenge for hospitals is patient satisfaction, which is commonly measured by reduced lengths of stays and prevention of re-admission. Lean can be a possible solution to these demands.

Lean helps increase value for patients by reducing wasteful activities through process optimization. Eventually, streamlined and simple processes will lead to fewer mistakes and higher quality, a better use of resources, and hence improved financial performance. From customer perspective, lean determines the value of any given process by distinguishing value-adding activities from non-value-adding activities, i.e., waste [2].

The lean approach was pioneered by Toyota's founder Taiichi Ohno and Shigeo Shingo as a technique of manufacturing automobiles in a faster and less costly manner. The term 'lean' was first coined by Womack, Jones and Roos [3] to describe the Toyota Production System (TPS) and the steps to continually improve the efficiency and effectiveness of system through elimination of wastes. According to Souza [4], it is a matter of debate when lean was first used in the context of healthcare, but the first publications are dated from 2002.

Simulation and lean are approaches that are rarely discussed together, particularly in the healthcare context. This is surprising given that they have a similar motivation: improvement of processes and service delivery. With the current focus on the efficiency of health services there has certainly been a growing interest in both simulation and lean, although that this has been largely along completely separate tracks. In particular, the role of simulation in the implementation of lean in healthcare will be explored. The aim is to improve the impact and engagement of both lean and simulation enabling them to work in a symbiotic relationship in improving healthcare systems.

In healthcare service, lean is a methodology that enables hospitals to improve patient care quality, support staffs and doctors, eliminate barriers and focus on providing care. Lean also facilitates coordination between disconnected departments, allowing different departments to work better together to benefit patients [5]. Over the last decade there has been a rapid increase in the implementation of lean in healthcare. In a recent literature review focusing on the use of process improvement methodologies in the public sector 51% of publications sources focused on lean, and 35% of the total specifically focused on lean in health services [1]. Indeed, lean in healthcare appears to have become widespread, especially in the USA, UK and Australia [4]. Tangible benefits have been reported where lean is being implemented such as reduction of processing or waiting time, increase in quality through a reduction of errors, a reduction in costs [6], alongside intangibles such as increased employee motivation and satisfaction, and increased customer satisfaction [7]. Chang et al. [8] showed that quality and efficiency can be improved simultaneously in hospitals. However, it is also important to note that many of these implementations have been confined to a single process or ward rather than a complete patient pathway which limits the scope of lean to improve healthcare processes [9].

Simulation has a much longer history in healthcare with regular articles on its implementation appearing from the 1970s [10]. Since the early 1990s there has been a huge increase, numbering thousands, in the number of articles being published on simulation in healthcare [11]. As for manufacturing, simulation promises many benefits for health applications including risk reduction for changes to processes, cost and lead time reduction, increased customer satisfaction and greater understanding of healthcare processes among their stakeholders [12]. However, these benefits are not necessarily being achieved with much evidence to suggest that simulation is simply not having the impact it could in the health sector [13].

The aim of this study is to apply one of the lean tools; Value Stream Mapping (VSM) to appraise the current condition of the test process and to use simulation model to propose alternatives which reduces the steps, waiting time, bottleneck present in the process. During appraisal of the current test process; various resources in the process, number of steps, Value Added (VA) and Non-Value Added (NVA) time and wastes prevailing in the process have been identified. Data has been collected by means of hospital log sheets, interviews, and on-site observations. After observing the current state scenario closely, a simulation model imitating the current state is formulated to confirm the verification of the simulation model. After numerous iterations, alternative scenarios are suggested that reduce the waiting time and bottleneck in the system without using additional resources.

2. Objectives of the study

- ✓ To identify the sequential process steps that take place when a request of a service is made by both the indoor and outdoor patients.
- ✓ To evaluate the potential areas of improvement of the existing facility through mapping.
- ✓ To suggest improvement guideline and compare the performance of the existing facility.

3. Methodology

This study is a case study based research. The action plan of the current research is shown in Fig. 1.

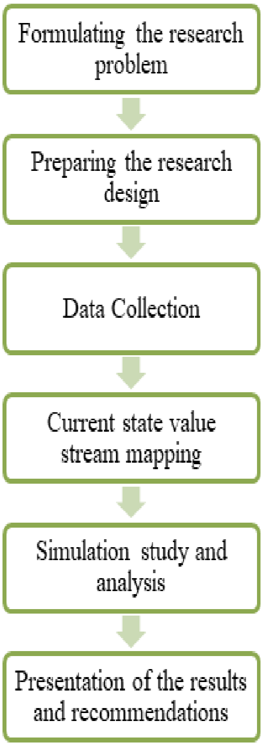


Figure 1. Flowchart representing the research methodology

4. Analysis and results

4.1. Existing system-an overview

The existing test procedure is illustrated in Figure 2. Based on the prescribed tests suggested by the physicians the patients make the payment. Since both indoor and outdoor patients pay in the same counter it is difficult to separate both type of patients. This study is therefore conducted considering both types of patients. After payment, blood samples are collected and sent to the pathology department for analysis. Then reports are prepared and sent to an expert for review. After a doctor has reviewed these test reports, reports are delivered to the desired patient.

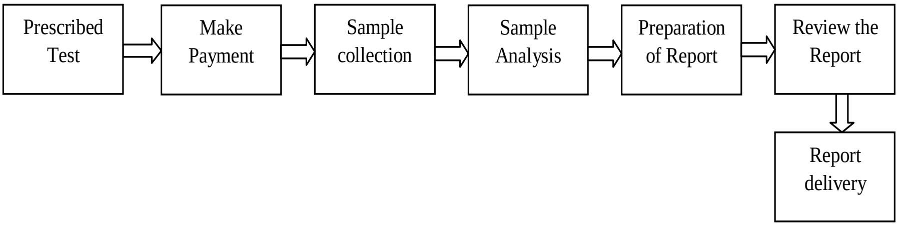
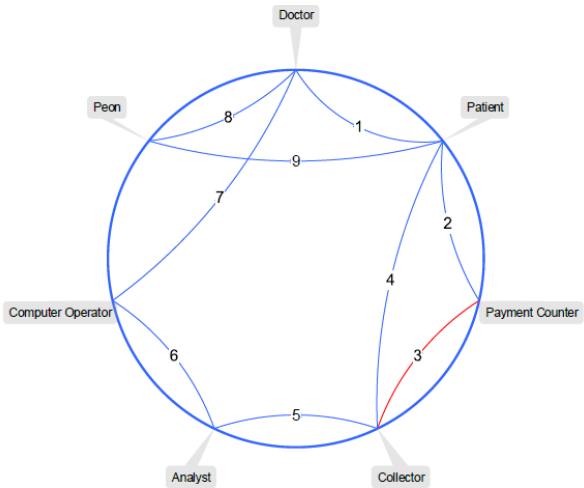


Figure 2. Steps involved in the existing process

4.2. Current State-Value Stream Map

An event circle allows visualizing the pathway or VSM. It shows the sequential interactions that occur between entities. The event circle of this VSM is shown in figure 3.



Number of steps = 9

Figure 3. Event circle of VSM of essential tests

The VSM of the essential tests was drawn using software named EVSM. In this VSM as shown in figure 4, process steps were identified which are shown using rectangular process boxes. Non-value adding activities/ wastes are shown using waste boxes which are in the interfaces of two process steps. Data were collected for each activity using data sheets. Time elapsed by each waste boxes were also measured.

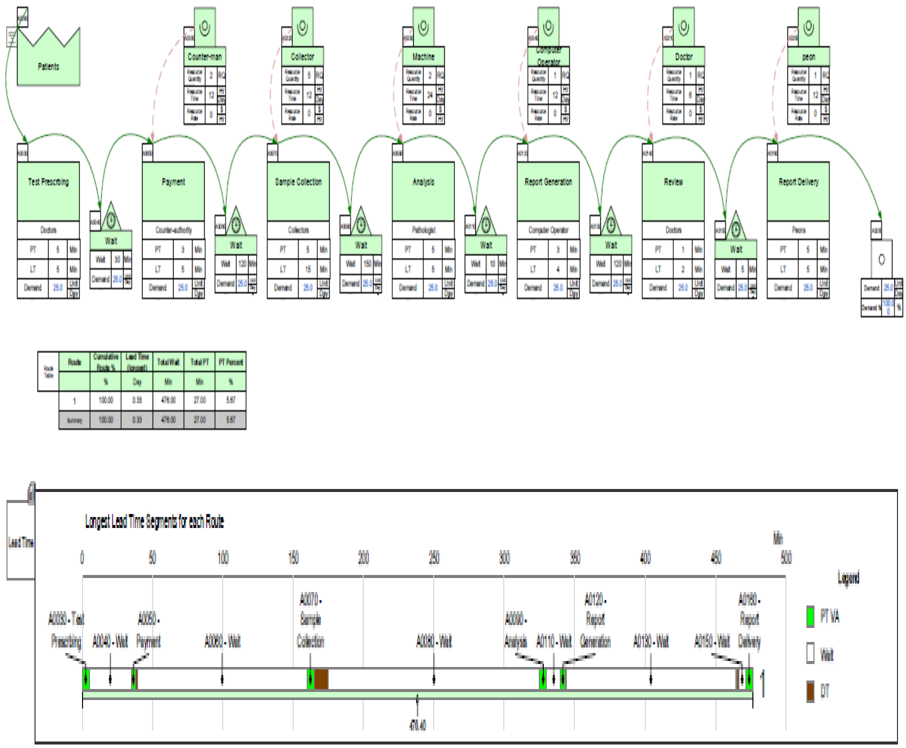


Figure 4: Current State-Value Stream Map of essential tests

4.3. Summary of Collected Data and Process Steps

Table 1 shows the average time required to complete each step and the waiting time in-between two steps.

Table 1: Time needed for each step (Average, Minimum and Maximum)

Value added and Non-value added activities	Process Time	Average Lead Time/ Average waiting time	Minimum Lead Time/ Minimum waiting time	Maximum Lead Time/ Maximum waiting time
1. Test Prescribing	5	5	3	10
I. W1*	N/A	30	15	180
2. Payment	3	5	5	15
II. W2*	N/A	120	60	300
3. Sample Collection	5	15	10	30
III. W3*	N/A	150	30	240
4. Analysis	5	5	5	5
IV. W4*	N/A	10	5	15
5. Report Generation	3	4	5	7
V. W5*	N/A	120	30	300
6. Review	1	2	2	4
VI. W6*	N/A	5	3	30
7. Report Delivery	5	5	5	15

*W1, W2, W3, W4, W5, W6 are non-vale added time between two subsequent processes

4.4. Evaluation of the Types of Wastes

Waste falls into one of following eight categories [2]:

- Conveyance
- Motion
- Waiting
- Over-processing
- Inventory
- Defects
- Overproduction

Different types of wastes in the current state VSM were identified so that these can be easily eliminated or reduced during the improvement phase. These are sequentially described below.

✓ **Wastes Due to Prescribing Tests**

Due to unavailability of Doctors and unorganized structure of test facility this waste is generated.

✓ **Wastes Due to Patient and their relatives**

In case of some indoor patients, after being prescribed to do a test, patients and their relatives were confused about whether to do the test in the hospital or not and it resulted in delay.

✓ **Wastes Related to Payment:**

Due to the queue in front of test counter, delay occurred.

✓ **Wastes due to inefficient flow of information:**

After the payment, the patient's information is given to sample collectors. As it is done via exchange of papers, it wastes a significant amount of time.

✓ **Wastes related to Sample Collection**

In case of indoor patients, sample collectors waited for ten test requests to be accumulated. It caused in a long waiting time. The collectors had to walk to each individual patient for sample collection so a significant amount of time was lost in transportation.

✓ **Wastes due to machines**

In some cases, there were long queues of tests in front of machine due to machine failure and malfunction.

✓ **Wastes related to Report Generation**

After the result of the test is generated, a computer operator was supposed to prepare the test reports but in many occasions he/she was unavailable. Also the number of computer operators was insufficient compared to the work demand put upon them.

✓ **Wastes related to reviewing**

A doctor was supposed to review the test reports after they were prepared and was sent to his/her desk. It has been found that this process step causes the most amount of time wastage.

✓ **Wastes due to Delivery problems**

After the review of reports, sometimes, the reports were not delivered timely to due to lack or absence of peons.

4.5. VSM of Outdoors

In this VSM, patients make request to be consulted by doctors. At first, a patient arrives at a payment counter and expresses their need regarding in which department he/she wants to go. Then, he/she (patient) makes the payment and collects the ticket of their desired department. After that, the patient reaches the waiting section of that particular department and waits there until called upon by the doctor. After being consulted by the doctors, the patient leaves the hospital.

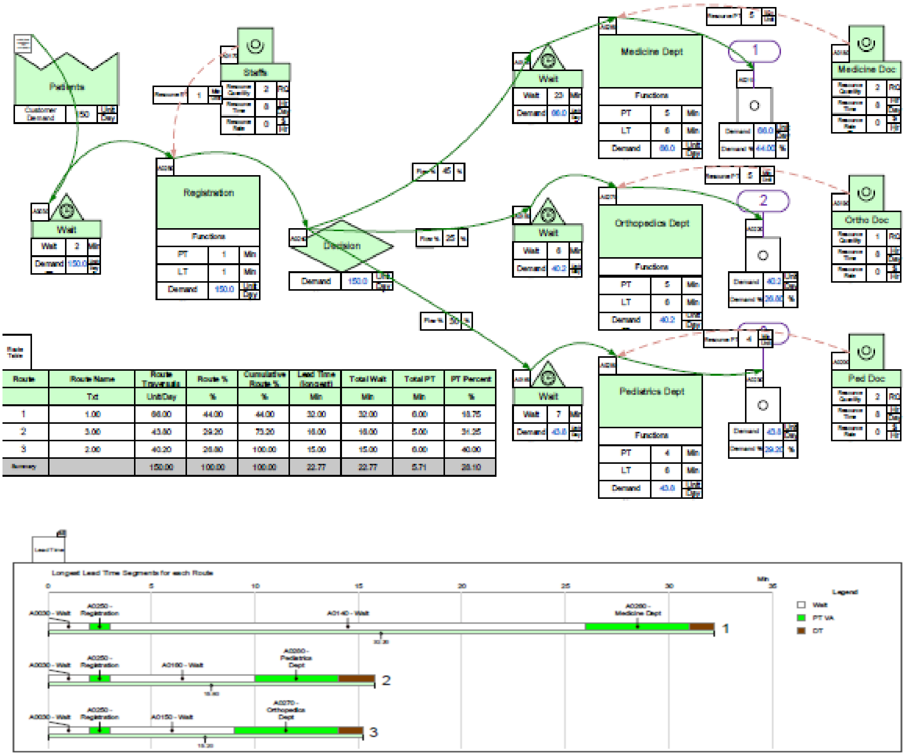


Figure 5: Current State-VSM of Outdoor Departments

4.6. Summary of Collected data and Process (Outdoors)

Three different outdoor departments have been chosen to collect data. These are: Medicine department, Pediatrics department and Orthopedics department. The summary of the collected data is shown in table 2.

Table 2: Time needed for each step
(Average, Minimum and Maximum)

Value added and Non-value added activities	Process Time	Average Lead Time/ Average waiting time	Minimum Lead Time/Minimum waiting time	Maximum Lead Time/ Maximum waiting time
1. Waiting in the queue	N/A	2	1	5
2. Registration	1	1	1	3
3. Waiting in the waiting room	N/A	Med: 23	18	29
		Ortho: 6	1	6
		Ped: 7	1	29
4. Consultation	Med: 5	6	3	7
	Ortho: 5	6	2	9
	Ped: 4	6	2	9

4.7. Evaluation of the Types of Wastes (Outdoors)

In the Current state VSM of outdoors, different types of wastes and problems had been found. These are sequentially described below.

- ✓ In the registration counter, there were only two staffs. Usually it was enough but could not able to properly serve when the number of incoming patients was higher than average.
- ✓ The number of seats in the waiting room was inadequate.
- ✓ Sometimes the doctors were absent or were busy with other tasks. It resulted in longer periods of waiting time for patients.

4.8. Simulation study

The simulation study has been only done for VSM of the essential tests because this process was more complicated and there were more opportunities for improvement. The existing system at the studied hospital is not modeled and simulated exactly the way it is due to natural variability's and unscheduled activities. Some assumptions for simulation study are:

- ✓ The simulation run time was 48 hours.
- ✓ The hospital started its operations at 8.00 am.
- ✓ The inter-arrival time depends on many factors, all of which could not be brought into consideration. The system under study ran from 8.00 am to 8.00 pm. For simplification, it was divided into two phases- one phase was from 8.00 am to 2.00 pm and another one was from 2.00 pm to 8.00 am. Data was collected separately for each of these phases.
- ✓ The doctors and employees shift and work hours were fixed.
- ✓ There were no allowances for the workers during the time when the model was running.
- ✓ The number of resources at each server was defined which was found out from collected data.
- ✓ Some process time data could not be collected due to various reasons. So, assumptions had to be made about them.
- ✓ There was no activity which caused any deviation from all the above assumptions.
- ✓ In case of scenario-II, six indoor departments were considered. The probability that the test request originated from any of those departments were assumed to be equal.

Data have been collected for inter-arrival times of patients and service times at each of the resource in the hospital.

The summary of no of resources at each server and their work-hours is shown in Table 3.

Table 3: No of resources at each server and their work-hours

Name of Server	Name of Resource	Work shifts	Number of Resources
1. Payment Counter	Counter Staff	12:00 AM to 8:00 AM	0
		8:00 AM to 2:00 PM	2
		2:00 PM to 8:00 PM	1
		8:00 PM to 12:00 AM	0
2. Indoor Sample Collector	Sample Collector	12:00 AM to 8:00 AM	0
		8:00 AM to 1:00 PM	3
		1:00 PM to 8:00 PM	2
		8:00 PM to 12:00 AM	0
3. Outdoor Sample Collector	Sample Collector	12:00 AM to 8:00 AM	0
		8:00 AM to 1:00 PM	2
		1:00 PM to 8:00 PM	1
		8:00 PM to 12:00 AM	0
4. Analyzer Machine	Machine	24 Hours service	
5. Report Generation	Operator	12:00 AM to 8:00 AM	0
		8:00 AM to 8:00 PM	1
		8:00 PM to 12:00 AM	0
6. Review	Doctor	12:00 AM to 8:00 AM	0
		8:00 AM to 12:00 PM	1
		12:00 PM to 4:00 PM	0
		4:00 PM to 6:00 PM	1
		6:00 PM to 12:00 AM	0
7. Report Delivery	Staff/ Peon	12:00 AM to 8:00 AM	0
		8:00 AM to 8:00 PM	1
		8:00 PM to 12:00 AM	0

4.9. Modeling of the System

The entire blood test process was divided into small processes to prepare the model in Simulation. Various modules e.g. creation, process, decision, delay, batch, assign, dispose etc. were used to imitate the real world scenario. The procedure that a test request follows at the hospital was divided into certain steps to create a flow in the simulation model. These steps were:

1. Arrival of the patient for making test request
2. Payment for test by the patient.
3. Decision for either the test request was for indoor or outdoor patient.
4. Collection of blood by the blood collector for indoor or outdoor patient.
5. Analysis of the blood sample by the analyzer machine.
6. Report generation by the computer operator.
7. Review of report by a doctor.
8. Report delivery to the desired patient.

In this model decision module was used determine the path of entity. Process module was used to calculate process time and the waiting time in queue. Batch module was used in certain cases to represent the real scenario where samples were stacked up for a process. The important parameters in this model are resources and queues. An overview of the model parameters are shown in the table 4.

Table 4: Model Parameters

Simulation model	Blood test process	Action
Resource 1	Payment counter person	Seize delay release
Resource 2	Indoor sample collector	Seize delay release
Resource 3	Outdoor sample collector	Seize delay release
Resource 4	Blood analyzer machine	Seize delay release
Resource 5	Computer operator	Seize delay release
Resource 6	Review doctor	Seize delay release
Resource 7	Delivery staff	Seize delay release
Queue 1	Payment counter	FIFO
Queue 2	Indoor sample collection queue	FIFO
Queue 3	Outdoor sample collection queue	FIFO
Queue 4	Blood analyzer machine queue	FIFO
Queue 5	Report generation queue	FIFO
Queue 6	Doctor review	FIFO

4.10. Interpretation of Results

The simulation produces a detailed and structured result which allows to view and analyze results by Entity, Process, Resource and others that are specified in the model.

✓ **By Entity**

The most important attribute attached with test entity (Test Request) is 'time'. Simuation gives a detailed output with Average value, Minimum, Maximum etc. for the various times that are observed by the entity during its stay in the system. In this model, the main outputs are the total time in the system, the wait time, value added time and non-value added time. The output from this model is shown in table 5.

Table 5: Total time per Test requests
(in minutes)

	Average	**Minimum Average**	**Maximum Average**	**Minimum value**	**Maximum value**
VA time	20.22	19.73	20.59	14.28	33.09
NVA time	23.23	22.43	24.21	15.74	29.71
Wait time	376.05	302.6	494.57	43.66	1542.2
Total time	419.5	345.73	538.37	86.25	1591.93

✓ **By Process**

Table 6, 7 and 8 shows the value-added time, non-value added time and wait time that was elapsed per test request in each of the processes.

Table 6: VA time per entity (in minutes)

Process	Average	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Payment	3.48	3.36	3.58	2	5
Indoor Sample collection	4.75	4.6	4.96	3.3	6.5
Outdoor Sample collection	4.79	4.72	4.83	2.98	6.45
Analysis	5	5	5	5	5
Report Generation	3.3	3.24	3.37	2.3	4.82
Review	1	0.95	1.01	0.54	1.48
Indoor Report delivery	9	8.36	9.36	5.04	14.69

Table 7: NVA time per entity (in minutes)

Name	Average	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Transportation time in Indoor collection	3.47	3.37	3.67	2	5
Operator Delay	7.65	7.18	8.45	5.42	9.89
Post Review Delay	10.93	10.66	11.32	7	15

Table 8: Wait time per entity (in minutes)

Name	Average	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Payment	0.4	0.22	0.58	0	10.55
Indoor Sample collection	6.88	6.04	7.49	0	19
Outdoor Sample collection	3.48	0.22	11.26	0	722.86
Analysis	0	0	0	0	0
Report Generation	56.2	30.21	143.41	0	782.42
Review	116.48	44.97	225.12	0	839.71
Indoor Report Delivery	0.04	0	0.16	0	1.78
Analysis Batch	136.42	92.17	203.96	0	1070.17
Indoor collection batch	203.07	130.75	319.15	0	1244.5

✓ **By Resources**

The average scheduled utilization of each resource is shown in table 9. From this table it can be seen that some resources e.g. server staff, computer operator, outdoor sample collector are highly utilized while others are not. These highly utilized resources are likely to cause bottlenecks in the system.

Table 9: Scheduled Utilization

Name	Average	Minimum Average	Maximum Average
Server staff	0.26	0.22	0.31
Indoor Collector	0.054	0.037	0.066
Outdoor Collector	0.27	0.24	0.31
Analyzer machine	0.0065	0.0052	0.0078
Computer Operator	0.32	0.27	0.37
Doctor	0.18	0.15	0.22
Delivery Peon	0.048	0.04	0.056

Table 10 shows the number of tests that were requested against the number of test requests that the system is able to fulfill.

Table 10: Entity entered vs. entity left

Name	Average	Minimum Average	Maximum Average
Number in	171	143	203
Number out	144	119	174

From these results, it can be seen that some resources were heavily utilized others are not. It made the total system unbalanced. There were very long waiting time in front of some servers which signified that those servers are in need of more resources. Moreover, the sample collection of the indoor patient was done when ten indoor sample requests are accumulated. This resulted in long waiting time and transportation time. In order to overcome these problems and constraints the two alternatives are suggested.

4.11. Suggested alternative Scenario I

In this scenario, some changes have been made according to the simulation study in the number of resources employed. The changes are given below.

- Schedule is such that one doctor is present from 8.00 am to 6.00 pm for report reviewing.
- In the payment counter, an additional staff have been employed and his/her work-shift was from 2.00 pm to 8.00 pm.
- Sample collectors is assigned for indoor patient's blood collection when 5 blood test requests are accumulated from indoor departments.
- An additional outdoor collector works from 1.00 pm to 8.00 am.
- An additional computer operator was employed for report generation who works from 8 am to 2pm.

These changes were applied to the current state simulation model and the obtained results are shown in table 11, 12, 13, 14. 15 and 16.

Table 11: Total time per entity (in minutes)

	Average	**Minimum Average**	**Maximum Average**	**Minimum value**	**Maximum value**
VA time	20.12	19.59	20.94	14.37	33.46
NVA time	22.88	21.94	24.07	15.86	29.67
Wait time	244.73	191.73	328.41	26.4	1214.47
Total time	287.73	234.19	371.02	63.01	1251.68

Table 12: VA time per entity (in minutes)

Name	**Average**	**Minimum Average**	**Maximum Average**	**Minimum Value**	**Maximum Value**
Payment	3.48	3.41	3.53	2.01	5
Indoor Sample Collection	4.79	4.65	4.87	3.22	6.39
Outdoor Sample Collection	4.81	4.76	4.87	2.93	6.49
Analysis	5	5	5	5	5
Report Generation	3.3	3.24	3.38	2.3	4.79
Review	0.99	0.96	1.04	0.53	1.48
Indoor Report delivery	9.02	8.66	9.66	5.21	14.61

Table 13: NVA time per entity (in minutes)

Name	Average	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Transportation time in Indoor Collection	3.48	3.34	3.57	2.01	4.98
Operator Delay	7.43	6.75	8.46	5.21	9.7
Post Review Delay	10.97	10.76	11.18	7	14

Table 14: Wait time per entity (in minutes)

	Average	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Payment	0.03	0.04	0.16	0	3.78
Indoor Sample Collection	2.22	2	2.38	0	8.96
Outdoor Sample Collection	4.9	0.03	14.96	0	720.79
Analysis	0	0	0	0	0
Report Generation	30.75	13.95	103.2	0	751.89
Review	54.25	0.13	126.68	0	839.22
Indoor Report Delivery	0.02	0	0.016	0	4.9
Analysis Batch	124.73	79.06	173.23	0	954.4
Indoor collection batch	88.33	48.2	137	0	999.17

Table 15: Scheduled Utilization

Name	Average	Minimum Average	Maximum Average
Server man	0.19	0.17	0.23
Indoor Collector	0.062	0.052	0.075
Outdoor Collector	0.18	0.16	0.22
Analyzer machine	0.0064	0.0052	0.0078
Computer Operator	0.17	0.14	0.21
Doctor	0.11	0.1	0.15
Delivery peon	0.049	0.033	0.065

Table 16: Number of entities entered against Number of entities left

Name	Average	Minimum Average	Maximum Average
Number in	177	155	213
Number out	154	134	201

4.12. Suggested alternative Scenario II

The sample collection for the indoor patients was prone to very long waiting time due to the batch system, in this scenario, an alternative indoor sample collection system have been suggested. In this system, nurses are given the responsibility of sample collection for the patients of their corresponding departments. In each department, a sample collection kit have been supplied. Whenever a payment is made at the payment counter, the indoor patient's information (Name, Bed number, Amount of sample etc.) are sent to the corresponding department which will be printed via a printer. That printer gets that information instantaneously from a central database connected to payment counter. According to the information, a nurse will collect the patients sample and store it. Every one hour lter, the samples which have been collected in that hour in that department are sent to analysis by a peon/staff of that department. Some other changes are given below.

- Schedule is such that one doctor is present from 8.00 am to 6.00 pm for report reviewing.
- In the payment counter, an additional staff are employed and his/her work-shift was from 2.00 pm to 8.00 pm.
- Sample collectors is assigned for indoor patient's blood collection when 5 blood test requests are accumulated from indoor departments.
- An additional outdoor collector work from 1.00 pm to 8.00 am.
- An additional computer operator is employed for report generation who works from 8.00 am to 8.00 pm.
- The simulation model of the alternative two and the corresponding results are given in table 17, 18, 19, 20, 21 and 22.

Table 17: Total time per entity (in minutes)

Name	Average	Minimum Average	Maximum Average	Minimum value	Maximum value
VA time	20.4	19.67	21.56	14.13	33.6
NVA time	24.06	23.45	24.76	17.38	31.22
Wait time	231.6	202.5	328.67	21.34	1103.51
Total time	276.06	246.72	373.41	57.31	1145

Table 18: VA time per entity (in minutes)

	Average	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Payment	3.5	3.43	3.59	2	5
Indoor Sample Collection 1	4.82	4.44	5.05	3.6	6.13
Indoor Sample Collection 2	4.78	4.52	4.98	3.59	6.35
Indoor Sample Collection 3	4.74	4.41	5.26	3.5	6.7
Indoor Sample Collection 4	4.6	4.22	4.9	3.31	5.66
Indoor Sample Collection 5	4.76	4.4	4.9	3.54	5.93
Indoor Sample Collection 6	4.86	4.52	5.4	3.56	6.25
Outdoor Sample Collection	4.83	4.75	4.92	2.93	6.5
Analysis	5	5	5	5	5
Report Generation	3.33	3.23	3.41	2.3	4.8
Review	0.98	0.95	1.01	0.52	1.48
Indoor Report delivery	8.86	8.45	9.3	5.4	13.94

Table 19: NVA time per entity (in minutes)

Name	Average	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Operator Delay	7.4	6.77	7.95	5.28	9.51
Post Review Delay	10.88	10.54	11.14	7	15

Table 20: Wait time per entity (in minutes)

	Average	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Payment	0.1	0.03	0.16	0	4.3
Indoor Sample Collection 1	0.11	0	0.44	0	4.88
Indoor Sample Collection 2	0.04	0	0.35	0	3.88
Indoor Sample Collection 3	0.06	0	0.36	0	4.37
Indoor Sample Collection 4	0.13	0.18	0.62	0	4.39
Indoor Sample Collection 5	0	0	0	0	0
Indoor Sample Collection 6	0.03	0	0.38	0	3.07
Outdoor Sample Collection	3.26	0.02	11.84	0	718.15
Analysis	0	0	0	0	0
Report Generation	43.97	14.46	116.95	0	743.33
Review	35.43	0.13	137.54	0	831.11
Indoor Report Delivery	0.009	0	0.06	0	3.1
Analysis Batch	135.24	75.58	181.94	0	1003.86
Indoor collection batch 1	27.09	17.21	36.44	1.61	57.41
Indoor collection batch 2	32.98	24.12	45.13	0.18	59.83
Indoor collection batch 3	31.07	6.24	41.59	0.58	59.59
Indoor collection batch 4	32.22	17.16	46.49	0.22	58.58
Indoor collection batch 5	29.17	21.27	35.5	0.07	58.29
Indoor collection batch 6	34.7	28.43	42.33	0.47	57.94

Table 21: Scheduled Utilization

Name	Average	Minimum Average	Maximum Average
Server man	0.19	0.17	0.2
Nurse (Average)	0.013	0.0031	0.02
Outdoor Collector	0.18	0.16	0.2
Analyzer machine	0.0064	0.006	0.0069
Computer Operator	0.17	0.14	0.18
Doctor	0.11	0.09	0.12
Delivery Peon	0.051	0.037	0.066

Table 22: Number of entities entered against entities left

Name	Average	Minimum Average	Maximum Average
Number in	203	180	220
Number out	181	157	193

4.13. Comparison of suggested alternatives which existenting situation

The total average time for current state and for simulation of scenario-I and scenario-II are respectively 419 minutes, 288 minutes and 276 minutes. Comarison of Value Added Time, Non- value Added Time, Wait time and Total time of current state, scenerio –I and Scenario-II is shown in figure 6.

Value-added quotient = $\frac{Value\ added\ time}{Total\ time}$

For current state, Value added quotient = $\frac{20\ min}{419min} \times 100\%$ = 4.77 %

For scenario-I, Value added quotient = $\frac{20\ min}{288\ min} \times 100\%$ = 6.94%

For scenario-II, Value added quotient = $\frac{20\ min}{276min} \times 100\%$ = 7.25%

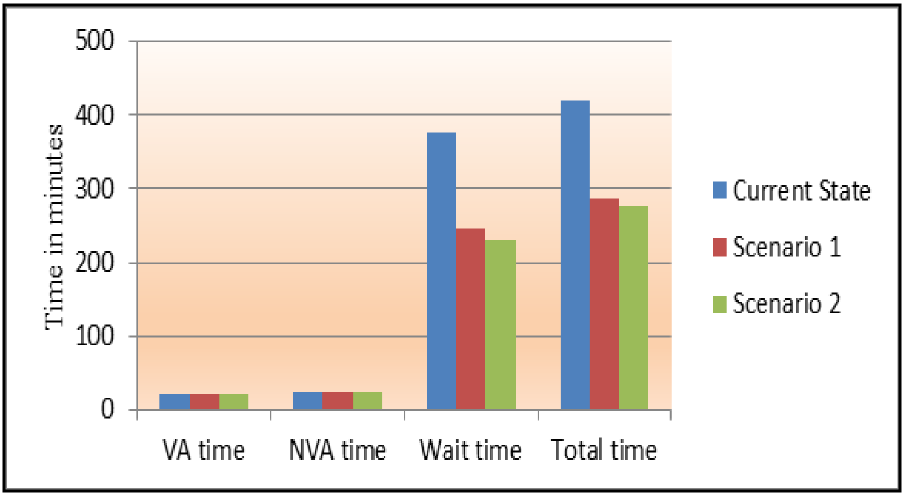


Figure 6: VA, NVA, Wait and Total time for current state, scenario-I and scenario-II

The resources are more balanced in scenario 1 and scenario 2 compared to the current state as shown in figure 7.

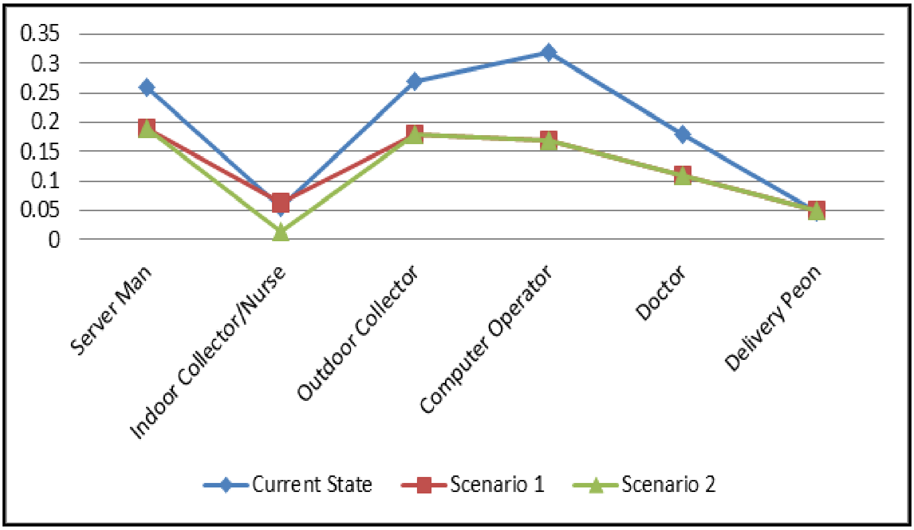


Figure 7: Comparison of scheduled utilization of resources

5. Discussion

The comparison of value added time (e.g. sample collection, analysis, report generation, review etc.), non-value added time (e.g. sample delivery delay, batch formation for analysis delay), waiting time among current state of the system, alternative scenario-I and alternative scenario-II are shown in figure 6. It is evident that the value added and non-value added time for the three scenarios are quite similar to each other. The waiting time on the other hand, which constitutes 88% of the total time in current state scenario is significantly reduced in alternative scenario-I and scenario-II by an amount of 131 minutes and 143 minutes respectively. Hence, the simulation runs provide an average total time of 288 minutes for alternative scenario-I and 276 minutes for alternative scenario-II; much less than the current state scenario which is 419 minutes.

Figure 7 compares the scheduled utilization of resources for the three scenarios. Mathematically, scheduled utilization is the percentage of the total time a resource has been busy divided by the total time it has been available. The more the percentage, the more time that resource has been occupied. It is quite misleading to think that more scheduled utilization means the system is working better. The discrepancy in the scheduled utilization of the resources means that one resource is busier than others which introduces bottleneck in the system. For a system to work properly, it is desirable to minimize the discrepancy among the scheduled utilization of resources as much as possible to minimize bottleneck in the system and to ensure a smooth flow of entities. In figure 7, the current state scenario indicates a huge discrepancy among the resources in the scheduled utilization which delineates presence of bottleneck in the system. Although, bottleneck has not been completely eliminated from the system in the suggested alternatives, it is far less compared to the current scenario.

Conclusions

In this study, a particular test process in a regional hospital was modeled and analyzed using VSM and improved using discrete event simulation. The goal of this study was to reduce waste in the form of waiting time and to reduce bottleneck to ensure smooth flow of entities. A current state VSM was developed to identify various types of wastes and bottlenecks and their causes. This current state VSM was used as a base to develop a current state simulation model which shows total time, waiting time, time per process and scheduled utilization. The results of the current state simulation run were used to suggest two improved alternative future state models which significantly reduced the waiting time from 376.05 minutes to 231.6 minutes, hence the total process time from 419 minutes to 276 minutes and increased the VA time quotient from 4.77% to 7.25%. The suggestions made in the form of two alternative scenarios proved to be aligning with the goal of this study as analysis of the simulation result shows reduction of waiting time and hence overall time of the process. The scheduled utilization also delineates that bottleneck has been reduced in the improved models.

Acknowledgement

Authors are thankful to Shahjalal University of Science and Technology Research Centre for providing research grant.

References:

[1] Radnor, Z.J. (2010). *Review of Business Process Improvement Methodologies in Public Services*. Advanced Institute of Management, London.

[2] Stevenson, W. J. (2015). *Operations management*. New York, NY: McGraw-Hill Education.

[3] Womack, J. P., D. T. Jones, and D. Roos.1990. The Machine That Changed the World: The Story of Lean Production. 1st ed. Philadelphia, PA: HarperCollins.

[4] Souza, L.B. 2009. "Trends and Approaches in Lean Healthcare." Leadership in Heath Services 22 (2): 121-139.

[5] Graban, M. 2012. Lean Hospitals – Improving Quality, Patient Safety, and Employee Engagement. 2nd ed. Boca Raton, FL: Taylor & Francis Group

[6] Silvester, K., Lendon, R., Bevan, H.R.S. and Walley, P. (2004). Reducing Waiting Times in the NHS: Is Lack of Capacity the Problem?, *Clinician in Management*, 12 (3), pp. 105-111.

[7] Radnor, Z.J. and Boaden, R. (2008). Lean in Public Services – Panacea or Paradox?, Public Money and Management, 28 (1), pp. 3-7.

[8] Chang, S.-J., Hsiao, H.-C., Huang, L.-H. and Chang, H. (2011). Taiwan Quality Indicator Project and Hospital Productivity Growth. *Omega*, 39 (1), pp. 14-22.

[9] Radnor, Z.J. and Holweg, M., (2010). From Tools to Systems: A Critical Appraisal of Lean Healthcare Implementations. *European Operations Management Association Conference.* Sousa R. Porto.

[10] Brailsford, S. and Vissers, J. (2011). OR in Healthcare: A European Perspective. *European Journal of Operational Research*, 212, pp. 223-234.

[11] Brailsford, S.C., Harper, P.R., Patel, B. and Pitt, M. (2009a). An Analysis of the Academic Literature on Simulation and Modelling in Health Care. *Journal of Simulation*, 3 (3), pp. 130- 140.

[12] Hollocks, B. (1992). A Well-kept Secret? Simulation in Manufacturing Industry Reviewed. *OR Insight*, 5 (4), pp. 12-17.

[13] Young, T., Eatock, J., Jahangirian, M., Naseer, A. and Lilford, R. (2009). Three Critical Challenges for Modelling and Simulation in Healthcare. *Proceedings of the 2009*

[14] International Relations and Security Network, Primary Resources in International Affairs (1972). Constitution of the People's Republic of Bangladesh.

[15] Rexhepi, L., & Shrestha, P. (2011). Lean Service Implementation in Hospital: A Case study conducted in 'University Clinical Centre of Kosovo, Rheumatology department'', (Dissertation). Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:umu:diva-38971