Improvement of Health Care System by Using Lean Tools: A Case Study

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Abstract. Densely populated countries like Bangladesh are facing challenges in the health care system with overcrowding, cost containment, and inadequate arrangement of the health care center in terms of increasing demand from patients. Running health care systems all over the country both private and public are unable to satisfy patients because of miss management, waste of time, and the lack of service. To identify and reduce the problem in the health care system, lean management plays an important role all over the world. Value stream mapping (VSM) is one of the proven widely used Lean techniques, to identify the flow of work, information, and structure for reducing waste of time and service stress which helps to make a good relationship between administration and service holder. VSM is a very primary stage in the Bangladesh health care system. This research aims to improve the health care system in Bangladesh and the study focuses on applying VSM at the cardiology department in Khulna Medical College Hospital, Khulna, Bangladesh. A patient survey is done for comparison of numerical results to real-life data in the cardiology department of Khulna Medical College Hospital. In this study it could be shown that after implementing the VSM technique, the patient capacity increased by 39%, Ideal time improve 9.62% as well as utilizing time increase by 38.46%. This result inspires large scale implementation of the lean tool in the health care sector of a country like Bangladesh.

1. Introduction
With 2.11% of the total world population, Bangladesh ranks number 8 in the list of countries by population[1]. Building a Safer Health Care System is a big challenge in a densely populated country like Bangladesh. Most of the people take health care facility from the government hospital in Bangladesh. Khulna medical college hospital is one of the vibrant hospitals which stands for Khulna division’s people, the southern part of Bangladesh. Due to heavy patient flow in the hospital, patients and staff are facing a lot of problems like long waiting, mismanagement, the lake of service, overcrowded, etc. To get out of this situation Meany research has been conducted. The lean tool is a common tactic to improve these difficulties in recent years[2]. After introduced by Toyota Motor, the manufacturing industry in Japan, Lean is successfully used in many industries to reduce waste, cost and employee empowerment for improving organizational processes [3–5]. Stone et. al. [6] explain lean as a continuous assessment tool, to remove waste or non-value-added activities from the organizational process. Value stem mapping is a strong tool that can reduce the problems [7]. VSM is one of the
preferred tools to visualize the process flow through a process mapping technique. VSM is an ideal tool to reduce waste and lead time in the cardiology department. There are two states in value stream mapping. Current state and second future state. The current state refers to the real value of this department, and future state refer to the goal of this department [8,9]. In one sentence lean is an operational Excellence. The focus on reducing waste differentiates Lean from other quality improvement methods. Lean starts by testing a system or at least reducing wasteful steps. Therefore, operations are divided into either value-added (VA) or non-value-added (NVA) through Lean standards. VA operations lead directly to meeting the needs of the consumer. NVA operations require time, space, or money and do not fulfill the needs of the client. 90 percent of activities are usually NVA, and 10 percent are VA. The direct inference is that the removal of the NVA process is more effective than enhancing the VA process. In health care, the patient is the client, and from the viewpoint of the patient, waste, or NVA processes are seen. One way of interpreting a VA approach is to view it as an expense that the patient will be able to pay for [5,8]. Patients would, for instance, pay for care but would not pay for waiting. Lean usually defines seven forms of waste, and an eighth is applied to health care. Long waiting time is one of the most important wastes of the health care system that can be reduced by lean tools. A value stream mapping technique is used in this study. If the waiting time is long patient satisfaction level is less. So, to reduce the long waiting time the lean tool is being used, and then patient satisfaction increases [5].

2. Method
About a total of 78 patients arrives in the cardiology department in Khulna Medical Centre daily. Only 15 number of are beds are existing. A total of 8 number of nurses are working per shift and 6 number of doctors are working per shift. Cardiology is the most valuable department in the healthcare system. So, the cardiology department of Khulna medical is being selected to perform this study. During the morning shift, which is from 8 am to 1.00 pm, the data for this analysis was obtained correctly from a cardiology department in Khulna Medical, where the maximum patient treatment is compared to another shift. The definition of waiting used in this research is the first-in, first-out (FIFO) queuing principle where the first patient arrives, the procedure system used as a tool to execute this analysis will first be served [7].

2.1. Identifying the major problem in the cardiology department
The major problems of healthcare identified by patient surveys. 10 survey questionaries are arranged to collect data from the patient. Many complaints are given. By the given survey data fishbone diagram is created. And it is shown the major problems of the cardiology department. About 130 patients are attended in this survey.
1. What is the major problem that you think in the cardiology department?
2. How much time to wait for your treatment?
3. What is the reason for the long waiting time that you think?
4. How friendly are the nurses?
5. How friendly are the doctors?
6. How satisfied you with the management system in this department?
7. How feeling about this environment?
8. Do you think diagnosis equipment is enough for this department?
9. How satisfied were you with your services?
10. What is the solution that you think to reduce this major problem?
About 130 patients attend this survey and the through valuable opinion to reduce the health care problems.

2.2. Fishbone analysis
By doing surveys valuable data is being collected. Some problems can be found in the cardiology department. Such as long waiting time, the lack of equipment, insufficient doctors and nurses, low management quality, corruption. But the major problem is being found in the long waiting time. Fishbone diagram is given below. Fig 1. Illustrated the fishbone diagram with survey data of the cardiology department to justify the major problem is long waiting time [6].
2.3. Reduce the identified problem in the cardiology department

To reduce the major problem of healthcare lean tool (value stream mapping) is being used. There are two states. One is the current state map other is the future state map. Value-added and non-value added is the major factor of the value stream mapping process. The current state map showed three operations of the process.

**Registration:** Registration is the first process, all patients attended the hospital and noted their detailed information. There is waiting time can be determined.

**Evaluation:** Blood pressure measurement, eco cardiology, high measurement, weight measurement are considered in the evaluation process. waiting time can be calculated by this operation. Nurse and staff can be a help to perform this operation.

**Treatment:** Primary treatment is done in this process. All patients wait for this operation. So waiting time can be calculated in this process. Doctors and nurses can help to perform this operation [5].

The waiting first time between registration and evaluation and second waiting time between evaluation and treatment is calculated by the queuing theory. Finally, by value-adding process improvement in the healthcare system.

2.4. Process flow diagram

The process flow diagram is shown in Figure 2. First of all, start the program then calculated the takt time of three operations then calculated the average cycle time of three operations then draw a current state map then analyze the value-added and non-value-added time finally draw the future map [10]

![Figure 1. Fishbone diagram](image)
2.5. The patient flow chart
Figure 3 demonstrates the patient flow chart, patients enter the registration room and listed their name and address. Then waiting for the evaluation process after finished the evaluation process finally, treatment is done by the doctors [11,12]

3. Data calculation
Takt time is an important method for determining the existing system under which additional maintenance is avoided. The takt time is better to calculate as it provides insight into patient expectations and allows for better observations during the initial process of mapping. The average number of total patient visits is 22 a day for the morning shift, according to the data collected. [13] For each service phase, therefore, the takt time is the same as indicated in Table 1
Takt time= Net available time divided by the demanded number for the same time for an identified time. For example, Admissions to attend 3 users in the 9 minutes available in the evening, they would have to attend one user every 3 minutes (9/3=3).
Cycle time (CT): Time spent between processes is called cycle time.
Batch size (BS): No of the units processed at the same time is called batch size
Operator time (OT): Time spent by each operator on each user to complete a process, based on direct observation at work
Work time (WT): Time available to meet the demand; calculated as shift time minus 30 minutes for each professional.
No of operators (NO): The number of key operators available during WT for each process attendance times.
Meantime spent waiting for first medical attention (TW1st MA): Time from end of triage to first medical attention (by a physician).

Available time = \( \frac{\text{Total time}}{\text{Total number of operation}} \)

3.1. Queuing theory to measure waiting:
The estimated number of clients denoted by 'Ls' in the system is the average number of clients, both waiting and in operation, in the system. The total number of customers waiting in the queue is the estimated number of customers denoted by 'Lq' in the queue. The estimated waiting period denoted by 'Ws' in the system is the average cumulative time spent on the system by a client. It is usually considered to be the waiting time plus service time. The expected queue waiting time denoted by 'Wq' is the customer's average time spent in the queue before the service starts. The server utilization factor denoted by 'P(= \lambda / \mu) (or busy period)' is the amount of time a server spends with clients. Here, 'λ' is the average number of customers arriving per unit of time and 'μ' is the average number of customers completing service per unit of time. The probability of queue size is greater than or equal to 'k' is given by 
\[ P(n \geq k) = \left( \frac{\lambda}{\mu} \right)^n \]
Average number of patient in the system, 'Ls' is given by
\[ L_s = \frac{\rho}{1-\rho} = \frac{\lambda}{\mu-\lambda} \]
Average number of patient in the queue 'Lq' is given by
\[ L_q = \frac{\rho^2}{1-\rho} = \frac{\lambda^2}{\mu(\mu-\lambda)} \]
Average waiting for time 'Ws' of a customer in the system including service time is given by
\[ W_s = L_s/\lambda = \frac{\lambda}{\mu(\mu-\lambda)} \]
Average waiting for time 'Wq' of a customer in the queue is given by
\[ W_q = L_q/\lambda = 1/ (\mu-\lambda) \]
The relationship between Ls and Ws (also Lq and Wq) is known as little’s formula [14,15]

3.2. Takt time for each operation:
Table 1 indicates the takt time of this cardiology department. Takt time means the total available number of times divided by the total number of patients in that operation. The total calculated time is 5 hours and the average number of patients is 22 so the takt time is 13.64 for each operation [8].

Table 1: Takt time

| Operation | Takt time |
|-----------|-----------|
| Registration | 13.64 min |
| Evaluation | 13.64 min |
| Treatment | 13.64 min |

3.3. Data collection:

Table 2: Data from the cardiology department

| Time of Day | Number of Patients | Registration (min) | Average Waiting Time (min) | Evaluation (min) | Average Waiting Time (min) | Treatment (min) |
|-------------|--------------------|--------------------|---------------------------|-----------------|---------------------------|----------------|
| 8:00 am to 1:00 pm | 1 | 1.4 | 2.6 | 4.6 |
| 2 | 1.3 | 3.2 | 5.2 |
| 3 | 1.1 | 4.2 | 8.3 |
| 4 | 1.2 | 3.4 | 7.3 |
| 5 | 1.08 | 3.9 | 9.1 |
| 6 | 1.5 | 3.8 | 12 |
| 7 | 1.3 | 4.83 | 3 | 10 |
All data are collected from the cardiology department. The selected time is the morning shift from 8 am to 1 pm. A total of 22 patients arrived in the registration booth average cycle time measured 1.14 min and calculated waiting time by queuing theory then the evaluation process is done. About 3.56 min cycle time for this process. Then the cycle time of treatment operation is measured.

Table 3: Average cycle time and available time

| Number | Operation  | Cycle time | Available time |
|--------|------------|------------|----------------|
| 1      | Registration | 1.14 min  | 300 min        |
| 2      | Evaluation  | 3.56 min  | 300 min        |
| 3      | Treatment   | 8.84 min  | 300 min        |
| total  |            | 13.54 min | 900 min        |

Data is collected from operation in a particular person. A stopwatch was used to measure data time.

4. Current state map:
For the entire method, Figure 4 shows the value stream map of the current state. Value-added, non-value added, waiting period, time occurs in the current state diagram, and Shift over Time (c/o) value which is believed to be 60 seconds. For each patient, the Change over Time (c/o) can be interpreted as preparation time. The cumulative lead time for the patient's process flow is 13.54 min for the current condition. Waiting time was recognized from the map as waste.
Figure 4. Current state map

4.1. Value-Added Time vs. Non-Value-Added:
Value-added time can be defined as the time, patient willing to pay, or the patient can perform any operational activity. Non-value-added time can be defined that patients not willing to pay. Cycle time performing time including in value-added time. Waste, waiting time, extra time including in non-value added. by reducing non-value-added patient satisfaction will increase. Value-added time is equal to the total cycle time of operation. None value-added time is equal to the total waiting & waste time in operation.

4.2. Identification of Waste and Data:

| Number | Operation | Cycle time(min) | No of Doctor / stuff | Available time (min) | Average number of patient(min) | Utilization time * cycle time (min) | Idle time(min) |
|--------|-----------|----------------|---------------------|----------------------|-------------------------------|----------------------------------|---------------|
| 1      | Registration | 1.14          | 1                   | 300                  | 22                            | 14.82                            | 285.18        |
| 2      | Evaluation  | 3.56          | 1                   | 300                  | 16                            | 46.28                            | 253.72        |
| 3      | Treatment  | 8.84          | 1                   | 300                  | 13                            | 114.92                           | 185.08        |
| total  |            | 13.54         |                     |                      |                               | 176.02                           | 723.98        |

Data from Table 4 reveals that the registration process has the highest idle period of 285.18 minutes among the three processes and the lowest period used since the number of systems in control is 1. The care process has the lowest patient count, which is just 13 patients a day. This is due to the long cycle time for the process, which is 13.54 minutes and is only carried out by 1 employee. It has the maximum amount of time used and the lowest amount of idle time. In addition, due to the small number of personnel, the care process often has the lowest ability to attend the patient, but a long cycle period to complete the process. This analysis marched the process and reschedules the employees to minimize the overall lead time and waste reduction.
5. Proposed Plan for Future Process Flow

The proposed plan for the future patient process flow is generated by implementing software in the arena simulation. Figure 5. (a) shows the number of total outputs from simulation software, (b) shows the waiting of each operation from the simulation.

![Figure 5. (a) simulation average number of outputs. (b) waiting time from simulation](image)

### Table 5. Future state map

| Number | Operation                      | Cycle time(min) | No of staff | Available time(min) | Average no of patient(min) | Utilize time=18*cycle time(min) | Idle time(min) |
|--------|--------------------------------|-----------------|-------------|---------------------|---------------------------|--------------------------------|----------------|
| 1      | Registration and evaluation    | 4.7             | 2           | 600                 | 28                        | 84.6                           | 513.4          |
| 2      | Treatment                      | 8.84            | 1           | 300                 | 18                        | 159.12                          | 140.80         |
| Total  |                                | 900             |             |                     |                           | 243.72                          | 654.28         |

As Table 5.1 shows the data of future state maps there the final output of about 18 patients will release from the treatment process. That value is collected from the arena simulation process. Then the utilization time of registration and evaluation is 84.6 min and treatment is 159.12 min. Then total idle time from registration and evaluation is 654.28 min and the total utilization time is 243.72 min. By increasing the usage time, decreasing idle time, and increasing the number of patients attended each day by retaining the number of staff in the clinic, the proposed improvement plan would influence the outcome. Besides, the patient's waiting period often decreases relative to the current process flow. [8].
Figure 6. shows the future state map for the cardiology department. There is a registration and evaluation process on the different floor then two processed are merged then the lead time is 30.21 min as same the value-added time is 13.54 min but the non-value-added time 4.83 min is being reduced and finally 16.67 min compared to the current state map and increased the utilization time. And finally increased the satisfaction level of patients.

6. Result and discussion

The output relation between the current state and the future state is shown in Figure 7. From the table, a patient's capacity is increased by 38% from 13 to 18 patients. The sum of idle time is also increased by 9.62%, which is decreased to 654.28 min from 723.98 min. The amount of time used also increased from just 176.02 minutes in the current state to 243.72 minutes in the future state. The percentage of improvement in capacity, idle time, utilization time, the number of operators, is 39%, 59%, 38%, and 33% that has a great impact on the cardiology department in Khulna medical. Patient satisfaction will increase and meet patient demand. The result may some differences compared to its simulation result. Some errors may cause deference such as calculating error, instrumental error, etc. This study is very important for the healthcare system, it refers to how to continuously improve in the health care system. And how to meet the patient demand properly. The main purpose of this study is to reduce the identified major problem. This study showed that how to identify the major problem and how to minimize the problem, the fishbone diagram is being used to identify the major problem, and value stream mapping techniques are used to minimize the major problem long waiting time. Finally, a maximum of 59% improvement can be achieved. That reduces the long waiting time. That great impact on the health
care system to increase the patient satisfaction level. Bangladesh is under development country but has a huge population in this country. As a result, many patients arrive every day but resources have not sufficient to perform corrective action. Much research is already done to improve health care. And its authority has already undertaken many attempts to improve the health system. This study helps to need proper action to increase the patient satisfaction level.

7. Conclusion
This study is significant for the healthcare system, it refers to how continually develop in the health care system. And how to better satisfy the patient's demands. The main purpose of this study is to reduce the identified major problem. This research shows that the fishbone diagram is used to define the main problem and how to mitigate the problem, to identify the main problem, and value stream mapping strategies are used to mitigate the long waiting time of the major problem. Finally, it is possible to reach a maximum increase of 59 percent. This decreases a long time of waiting. That large impact on the health care system to increase the level of patient satisfaction.

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