Improving Performance of Epidemic Healthcare Management during COVID-19 Outbreak using LSS DMAIC Approach: A Case Study for Bangladesh

Aquib Irteza Reshad, Md. Mozibur Rahman and Naquib Mahmud Chowdhury
Department of Industrial and Production Engineering
Bangladesh University of Engineering and Technology(BUET)
Dhaka-1000
reshad10810@gmail.com, muzib.ipe@outlook.com, naquibmahmudchowdhury@gmail.com

Abstract

The recent outbreak of coronavirus (COVID-19) pandemic has exposed the weakness of the existing healthcare facilities in developing countries like Bangladesh. The increasing amount of patients has made this condition more vulnerable. There is a high possibility that, these increasing amount of symptomatic patients might create a shortage in RT-PCR test kits in upcoming days. The objective of this study is to use Define, Measure, Analyze, Improve, and Control (DMAIC) in improving the epidemic healthcare management system during the COVID-19 outbreak in Bangladesh. The goal of this study is to use LSS methodology, especially the DMAIC improvement format in the existing dedicated healthcare management system for coronavirus treatment. The root cause analysis behind the higher response time and improper service for the Institute of Epidemiology, Disease Control and Research (IEDCR), and other dedicated healthcare providers regarding, coronavirus treatment in the current situation has been performed. FMEA (Failure Mode and Effect Analysis) was conducted in order to assess the potential failure modes in the existing healthcare management system. A simulation study regarding the implementation of pooled testing in Bangladesh for improving efficiency and optimizing the usage of RT-PCR test kits has also been carried out. Subsequently, the feasibility study of implementing the pooled testing methodology was performed. Finally, recommendations and conclusions have been presented.

Keywords
COVID-19, Epidemic Healthcare Management, DMAIC, Lean Six Sigma, Pooled Testing Methodology

1. Introduction

The ongoing pandemic of coronavirus disease 2019(COVID-19) caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was first identified in Wuhan, China in December, 2019. Till April 28, 2020, more than 3 million people from 210 different countries have already tested positive for this virus and among them more than 215,000 people died and near about 1 million people has already recovered. The number of the infected patients are increasing day by day which has already created severe difficulties in providing appropriate healthcare support in the hospitals and other healthcare institutes. At the same time, the increasing number of symptomatic patients from coronavirus disease have resulted into a huge demand of RT-PCR test kits. Developing and underdeveloped countries have high possibility that, they might encounter shortage of test kits in the upcoming days.

The first three known cases of Bangladesh were reported on 7th March by the country's epidemiology institute, IEDCR. In Bangladesh, till April 28, 2020, 6462 people have been tested positive and 155 people have already died from this virus. The increasing patient have already created massive problems with the available inadequate healthcare facilities. Apart from that, the outbreak of coronavirus disease has already created disruption in the treatment of patients suffering from other diseases. Subsequently, many denial or, delayed cases of treatment for patients suffering from other diseases' rather than COVID-19 from different healthcare facilities, all over the country, have been reported numerously since the outbreak of this virus. Since, Bangladesh haven't reached to the peak requirements of healthcare support regarding the COVID-19 pandemic yet, it is evident that, these challenges will certainly increase in the upcoming days.

According to Bangladesh's constitution, government is committed to "supply the basic medical requirements to all segments of the people in the society" and "the improvement of the nutritional and public health status of the people". Quality of healthcare in Bangladesh is based on the accreditation of Ministry of Health and Family Affairs, Bangladesh. Under the ministry and directorate general of health services (DGHS), many institutes, healthcare facilities, medical colleges etc. are being operated to provide healthcare support and related activities. The ministry is dedicated to stimulate continuous and systematic improvement in the existing healthcare institutes of Bangladesh. Among the institutes, Institute of Epidemiology, Disease Control and Research (IEDCR) was established in 1976 for epidemiological and communicable disease research as well as functioning of disease control programs mainly in the form of parasitic and entomological containment of vector borne diseases through application of epidemiological principles. This institute is currently performing the prime role for clinical management of COVID-19 patients in Bangladesh. Some other designated healthcare institutes and facilities are also taking part in performing RT-PCR tests and providing related healthcare support to the respective patients. But due to many difficulties and related challenges, the performance and support services of these institutes and healthcare facilities are not adequate and up to the mark. For achieving higher service rate and providing required healthcare support in these healthcare institutes in upcoming days, implementation of LSS methodology along with DMAIC improvement format can be an excellent approach.

As this COVID-19 pandemic has created a vulnerable situation in the healthcare industry, and the number of affected patients are increasing, the objective of this study is to implement lean six sigma and DMAIC methodology in order to improve the performance of epidemic healthcare management system in Bangladesh.

2. Literature Review

Since the 1990s, lean management principles are being discussed, debated and deployed in healthcare sector as a mean to remove excess waste and improve quality. Healthcare management system is facing new challenges and opportunities from a rapidly changing operating environment, including increasing expectations on the quality of healthcare. Although, lean concept was originally developed in the automotive industry to deliver high quality product and services while improving organizational performance and satisfying customers, it can be also used in increasing expectations for quality healthcare services (Leslie et al. 2006). Bahensky et al. (2005) stated that, lean initiatives do not focus on large scale investments, but it give healthcare institutes and organizations an alternative methodology for achieving continuous improvement without high investments. Fosdick and Uphoff (2007) stated that, hospitals are suitable choices for applying Lean techniques largely as a result of the continued use of processes and care delivery sites that were developed and designed decades ago. They identified how Lean methods have been implemented successfully at the Nebraska Medical Center in order to eliminate bottlenecks and reducing specimen turnaround time, as with complete blood counts, by 20%.

The application of six sigma in healthcare industry is comparatively a new ideology and very few research has been performed in this area. Researchers and practitioners who are currently engaged in six sigma research are finding this industry highly valuable. Taner et al. (2007) found that the healthcare organization has a greater ability to address challenges across the system through the implementation of lean six sigma. Resource utilization can be maximized along with the observation of fewer redundancies, waste and rework. Bottle-necks related to scheduling was also diminished through it. Working conditions was improved for healthcare personnel through implementation of DMAIC methodology. Increased patient and physician satisfaction as well as cost savings were achieved. They forecasted that, implementation of lean six sigma will enable the healthcare organization to increase its market share in the long run.

Hagg et al. (2007) stated that Lean is an effective tool for identifying and eliminating waste from process. The primary objective of applying lean in healthcare is to reduce wastes, minimize waiting times and optimize travel routes, while ensuring better quality, faster service and more flexibility into the healthcare facilities and institutes. Dahlgaard et al. (2007) defined Lean Healthcare Practice is to develop healthcare culture characterized by participation of every related personnel in the process of identification and reduction of wastes in order to ensure satisfaction of the increasing patients and other stakeholders. Many healthcare organizations is currently practicing Toyota Production Systems (TPS) for performance improvement which is often called the Lean Healthcare management System. It is a system designed for providing tools to people in order to ensure continuous improvement in healthcare activities and adding value to the service being delivered. (Poksinska 2010).

Rexhepi and Shrestha (2011) emphasized on the high necessity of implementing lean in the healthcare sector for service improvement. They also mentioned that, implementation of lean is not only applicable in hospitals, but also in the private clinics, nursing homes and other healthcare providers.

Lean concepts have been used previously in pandemic healthcare management. Isaac-Renton et al. (2012) used the multidisciplinary response and rapid implementation of process changes based on lean methods at the provincial public health laboratory in British Columbia, Canada, to improve laboratory surge capacity in the 2009 influenza pandemic. They showed that, use of lean tools successfully expanded surge capacity, which enabled response to the 10-fold increase in testing demands observing the computer simulating evaluation results from rapid processes changes.

Define, Measure, Analyze, Improve, and Control (DMAIC) improvement tool has been used previously in implementing lean methodologies for improving healthcare facilities. Benitez et al. (2007) reduced medication errors using DMAIC approach in hospitals and other healthcare institutes. Southard et al. (2012) used DMAIC approach and drew on various analytical tools such as work flow diagrams, value stream mapping, and discrete event simulation to examine the effect of implementing RFID technology on improving effectiveness (quality and timeliness) and efficiency (cost reduction) of outpatient surgical processes in different hospitals.

3. DMAIC Methodology

Lean Six Sigma (LSS) is considered as a process improvement methodology (Pamfilie et al., 2012) which integrates two separate and distinct management concepts: Lean and Six-sigma (Pepper and Spedding, 2010) complementing each other in order to improve organizations' processes and results. This whole integration has been achieved through mixing these methods and principles (George, 2003) using the DMAIC (define, measure, analyze, improve, control) cycle as the conjoint continuous improvement framework (Cheng and Chang, 2012). Sokovic et al. (2010) referred DMAIC (Define, Measure, Analyze, Improve, and Control) to be a data-driven life-cycle approach to Six Sigma projects for improving process; it is an essential part of a company's Six Sigma program. DMAIC is an acronym for five interconnected phases: define measure, analyze, improve and control. The simplified definitions of each phase are:

- **Define** by identifying, prioritizing and selecting the right project,
- **Measure** key process characteristic, the scope of parameters and their performances,
- **Analyze** by identifying key causes and process determinants,
- **Improve** by changing the process and optimizing performance,
- **Control** by sustaining the gain.

The flowchart showing the functions of DMAIC methodology is given below:

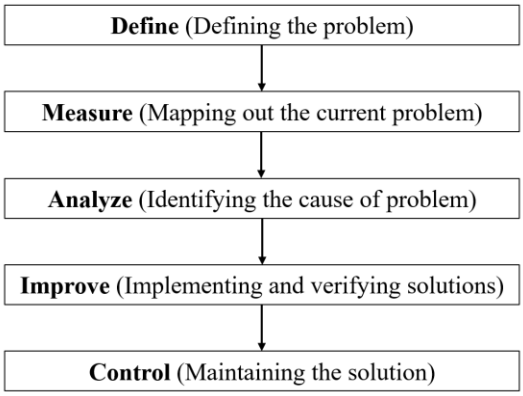

Figure 1: DMAIC methodology

3.1 Define

This is the most vital step of DMAIC process as the success of the project greatly depends on this. In this step, the problem to be solved is defined and the problem should also be manageable. SIPOC analysis has been performed in this 'Define' phase. Glover (2005) defined SIPOC as a structured process, where the suppliers, inputs and outputs of a process and customers are identified. Antony et al. (2012) stated that, SIPOC diagram is generally used to identify all relevant elements of a process improvement project before work begins. It is used to define business processes where the team identifies and maps the basic relationships between the suppliers, inputs, process steps, outputs and

customers, hence called a SIPOC diagram. The SIPOC diagram is usually developed by the Six Sigma team after brainstorming and discussion with the associated stakeholders.

For IEDCR, Bangladesh, the process starts with the call from a potential COVID-19 patient who have developed some symptoms related to COVID-19 and the supplier (IEDCR along with other healthcare institutes) supplies its products (services like sample collection, testing specimen, providing reports, taking COVID-19 infected patients into isolation, giving treatments and necessary health supports etc.) to the customer. Currently, around 80,000 calls are received through IEDCR hotlines per day in Bangladesh and among them only around 4000 patients' specimen are collected due to the lack of manpower and RT-PCR testing kits. The data of recent five days is given in table 1. Though, the World Health Organization (WHO) has already suggested to perform tests as much as possible for potential symptomatic patients to isolate the confirmed COVID-19 patients as early as possible. Since, COVID-19 patients are carrier of this deadly virus, early isolation and proper treatment of them will ensure lower rate of community transmission. Unfortunately, this cannot be made possible for various reasons which will be discussed in the later sections. The SIPOC diagram for the healthcare management process during COVID-19 is given below:

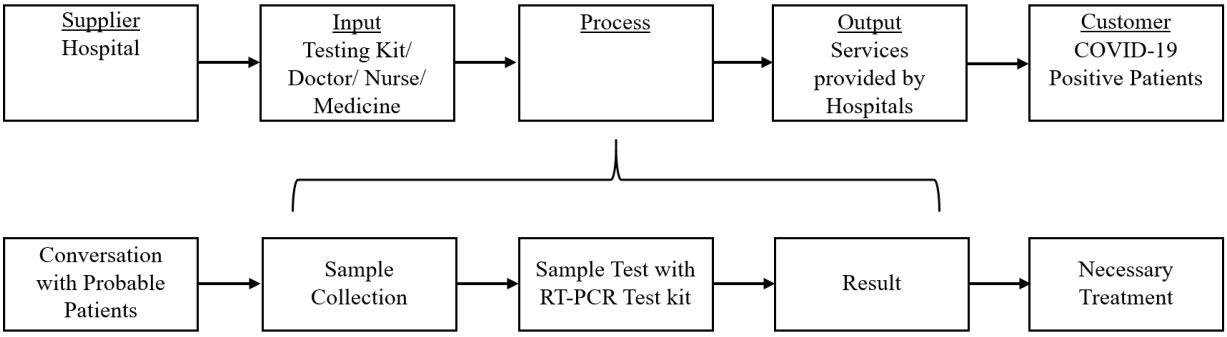

Figure 2: SIPOC diagram

3.2 Measure

The ultimate goal of this 'measure' step is to understand the whole process and the measures to express the performance of the current process. The Measure phase is generally based on numerical studies and data analysis. It focuses more on data analytics compared to the Define phase. This phase validates the measurement system and works to figure out the associated root causes for those problems.

For this reason, a process flow chart has been developed to better demonstrate the process. There we can see a potential patient of COVID-19 calls in the IEDCR hotline to tell his/her developed symptoms and after the conversation, the Medical Professional, based on experience, decides whether the patient should be tested or not. The respective medical professional also provides related supportive information to the caller regarding his developed symptoms. Generally, within 48 hours, specimen collection and testing is done. Sometimes because of any kind of inconvenience, some specimen are not tested on the same day of collection. The result is published in digital manner through SMS. After that, the patient is treated according to their condition. If their condition is critical, then they are hospitalized in the designated hospitals for COVID-19 patients. Mild symptomatic patients are kept in isolation in their own house. So, generally, it takes about 24-48 hours for a patient to get a result since, the phone call is done.

The process flow chart demonstrating the overall process which is being performed by IEDCR, Bangladesh is given below:

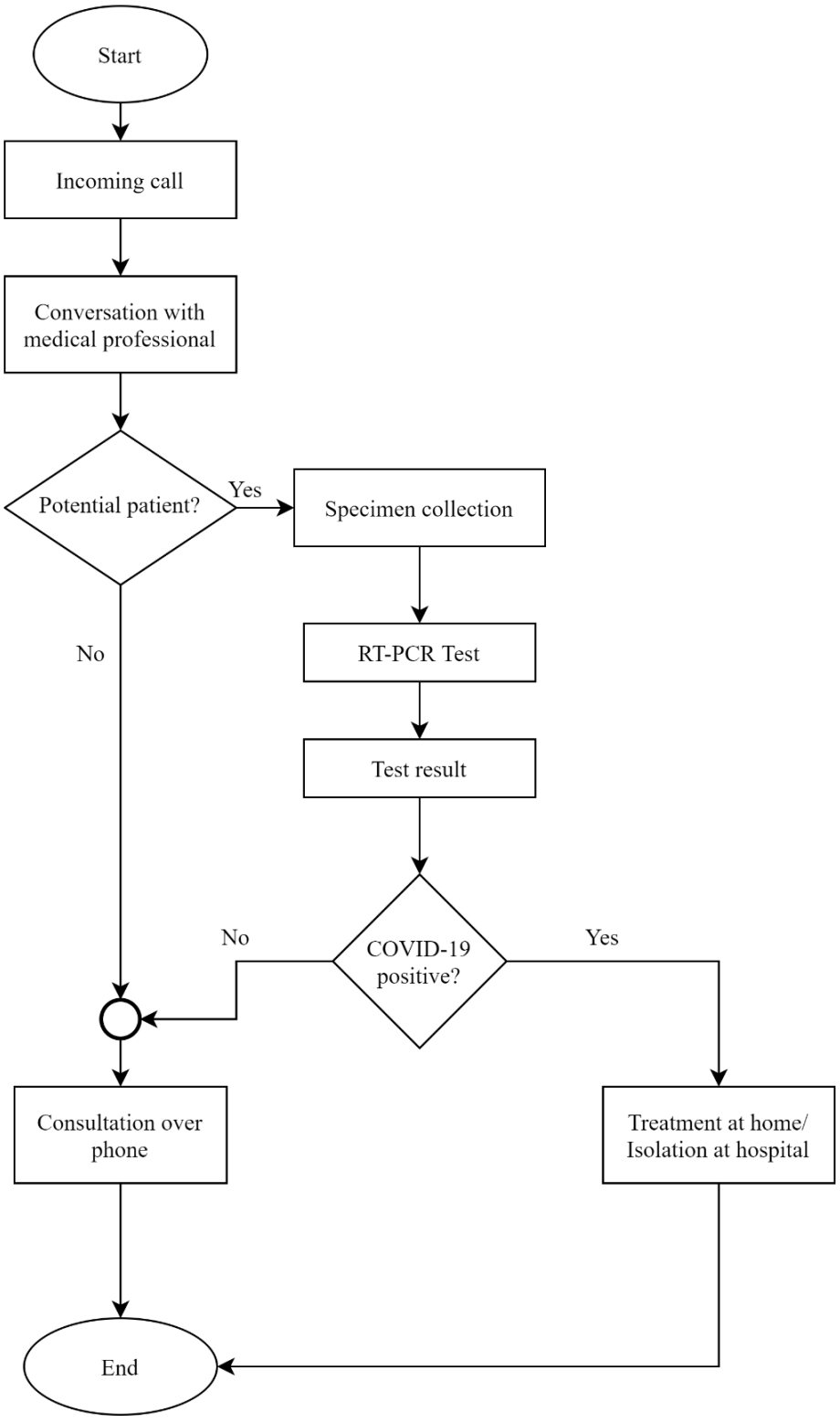

Figure 3: Process flow chart of IEDCR, Bangladesh

3.3 Analyze

Probable sources of variation are found in this steps. To obtain this goal, a fishbone diagram has been developed. Four main sources of variation were found for this process which are man, management, method and machine.

Corruption has always been a concern for Bangladesh. Due to corruption, mismanagement is seen everywhere. Again because of political pressure and other related causes, some patient get priority though there are more critical emergency cases pending.

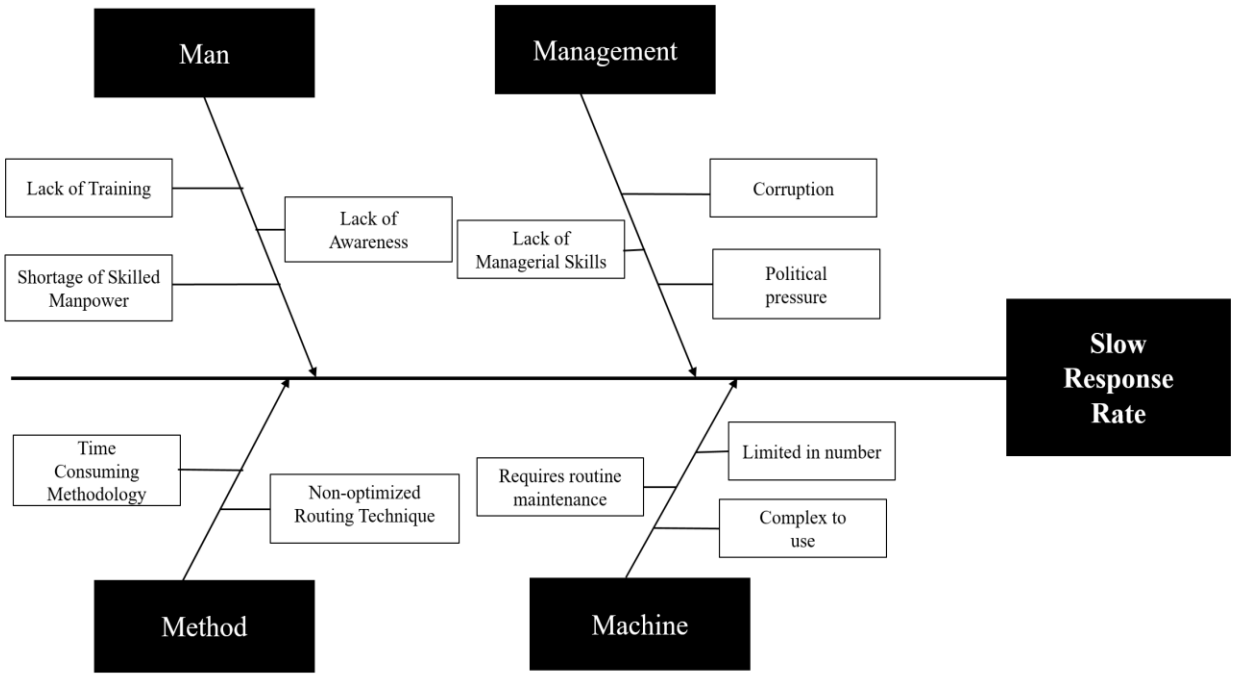

Figure 4: Fishbone diagram for analyzing the cause and effects behind slow response rate

The people are also not that much aware and serious about the present situation and thus waste valuable time by giving misleading calls to the hotline numbers. Shortage of manpower and lack of proper training creates problem to maintain a smooth response.

The method of testing is much time consuming and lack of experienced manpower adds a ton to this problem. Following a non-optimized route increases the time to collect sample and thus decreases the overall capability of the testing numbers.

Although, the number of machines are expanding, but it is not enough for the huge number of tests required. The number of RT-PCR testing kits are also limited which is creating pressure for lowering down the number of tests as much as possible. RT-PCR machines need well trained personnel for proper maintenance and operation, but there exists shortage of skilled and trained personnel.

3.4 Improve

The improvements that have been developed are showed in this phase. Some pilot test can be applied to the system to see if the improvements are feasible for the system or not.

The Failure Modes and Effects Analysis (FMEA) table has been developed for this purpose. It is a simple tool to detect the most critical failure mode and take steps accordingly to eradicate it from the system. First of all, the possible failure modes are identified. Then, their possible causes and effects on the system are described. A Risk Priority

Number (RPN) number is obtained for each failure mode that were analyzed based on their probability of occurrence, probability of detection and also the severity of that failure mode on the system.

Table 1: FMEA analysis of the system

Steps In The Process	**Failure Mode**	**Failure Causes**	**Failure Effects**	**Likelihood of Occurrence (1-10)**	**Likelihood of Detection (1-10)**	**Severity (1-10)**	**Risk Priority No.**	**Recommended Corrective Actions**
Call from Potential Patient through IEDCR Hotline	Misleading calls or, calls not related to coronavirus disease	Lack of awareness regarding seriousness of the situation	Wastage of time and delay in attending calls of potential patients	2	1	5	10	Creating proper awareness among mass people regarding COVID-19
	Failure in recognition of patient	Patients unable to express the symptoms properly	Increasing patients from community transmission, failure in identification of positive patients	8	10	10	800	Performing higher number of RT-PCR tests for both mild and serious symptomatic patients
Sample collection	High Sample Collection Time	Not following optimized route/Lack of experience	Reduction in number of collected samples	10	8	9	720	Following optimized route for specimen collection, recruiting skilled personnel
	Contamination of sample	Lack of proper training	Give faulty result	7	8	10	560	Training human resources
Sample Testing	RT-PCR machine failure	Improper maintenance/ Untrained people	Delay of result	5	5	10	250	Routine maintenance and training human resources
	Slow Procedure	Lack of experiences, Shortage of skilled human resource	Delay of result	10	2	10	200	Training human resources

In the existing condition, the system is failing in recognizing a patient to be selected for RT-PCR testing criterion. The most critical failure mode is followed by using non-optimized route and contamination of sample. For eradicating these failure modes, related proposals or, suggestions are described below:

Following an optimized route for specimen collection

Using an optimize route can reduce the time to collect specimen to a significant level. Following an optimized route rather than a non-optimized route will eventually result in minimizing the specimen collection time. Reduced time in specimen collection procedure will result in increment of the total capability of the specimen collection system. A sample problem has been solved for showing the usefulness of the effective routing.

Stop	Order ID	Location Name
0	0	IEDCR
1	Order 3	Azimpur
2	Order 2	Farmgate
3	Order 5	Kolabagan
4	Order 4	Kollanpur
5	Order 6	Kollanpur
6	Order 1	Tolarbaag
7	Order 8	Mirpur 12
8	Order 9	Mirpur 11
9	Order 7	Mirpur 12
0	0	IEDCR

Figure 5: Sample optimized route solve by Google Sheet

A random 9 places were selected for specimen selection around Dhaka, Bangladesh and optimizing the route was performed by using 'vehicle routing problem' approach through Google Sheet. The result gave an optimized route which would take only 37 minutes to travel the whole distance. This can be easily done and used in minimizing the time.

Proper training of medical professionals and technologists

From the collection of specimen to RT-PCR testing and providing results, the whole process is highly sensitive. Some complaints have found through news and broadcasting media on activities of the personnel involved in the overall process. Shortage of skilled and trained manpower is quite evident. Proper training for obtaining skilled manpower will ensure lower rate of contamination in the sample, quick and prompt response, better healthcare service and higher accuracy in the overall testing procedure.

Pooled Testing

Limited number of machines and kits has made it difficult to test a large amount of symptomatic patients. The scarcity of testing kits might get more vivid in coming days due to increasing symptomatic patients. So, the higher rate of community transmission will result in more cases of COVID-19. Thus, a COVID-19 positive patient can go without testing and spread the virus to other people. So, the most important step that should be taken at present is to increase the number of testing. For this purpose, the usage of kits can be optimized to increase its efficiency. Pooled testing can be a good solution to this.

Wein and Zenios (1996) studied pooled (or group) testing as a cost-effective alternative for screening donated blood products (sera) for HIV; rather than test each sample individually. They combined various samples into a pool, and then tested the pool. According to them, a group testing policy specifies an initial pool size, and based on the HIV test result, either releases all samples in the pool for transfusion, discards all samples in the pool, or divides the pool into sub-pools for further testing. The concept behind pooled testing is to mix a number of specimen together and if the result is negative then all of the aggregated specimen are negative and if positive result is found the samples are to be tested in the conventional process again. Some European countries have been successful in increasing the efficiency of test kits through implementing pooled testing for SARS-CoV-2. Bukhari et al. (2020) studied pooled testing methodology and found that, use of smart pooled sample testing with the help of algorithms may be a quite useful

strategy in the current prevailing scenario of the COVID-19 pandemic. With the help of this strategy, the optimum number of samples to be pooled for a single test may be determined based on the total positivity rate of the particular community.

A simulation has been done based on the data of Bangladesh which is collected from COVID-19 dataset of WHO. The result shows that, pooled testing can significantly reduce the number of testing kits used by almost 30%. So, the remaining resources of test kits can be utilized in detecting more Covid-19 positive patients and give them proper treatments. For all the aggregation of sample, simulation has been performed 100 times and then average results have been shown in the table. The result shows that, aggregating 4 sample together can give the best result and reduce the need for testing kits to a significant level thus increase the capability. The problem with increasing aggregation size is that, when an aggregation is found to be positive, the exact individuals with positive result are to be identified, hence, divide-and-search operation is to be carried out up to the individual identification point.

Table 2: Simulation result for pooled testing procedure

Date	Total Test	Positive Cases	Required number of test kit when aggregating 4 samples	Required number of test kit when aggregating 8 samples	Required number of test kit when aggregating 16 samples
24 April, 2020	3686	503	2675 (72.6 %)	2850 (77.34%)	3033(82.29%)
25 April, 2020	3337	309	1960(58.765)	1993(59.7%)	2111(63.2%)
26 April, 2020	3476	418	2350 (67.63 %)	2472 (71.14 %)	2633 (75.77 %)
27 April, 2020	3812	497	2698 (70.8 %)	2859 (75.02 %)	3047 (79.95 %)
28 April, 2020	4332	549	3018 (69.68 %)	3191 (73.68 %)	3390 (78.27 %)

Spreading Awareness

As people are not that aware of the current situation, they do not take this seriously and act responsibly. To solve this problem, print, electronic and social media can play a prime role. Programs related to this pandemic should telecast more to make the people aware and conscious. The creation of awareness will ensure people to follow proper guidelines regarding COVID-19 and act responsibly.

Following Proper Questionnaire in Hotline Communication

When a call arrives in the IEDCR hotline, the medical professional should ask questions in sequential pattern so that, the real symptoms can be found easily. The questionnaire should be followed strictly while communicating with a potential patient of COVID-19. This will reduce the both time and effort while communicating with the patient and ensure higher response.

3.4 Control

Control phase is the final stage where monitoring tools like control charts, statistical analysis are used to monitor the process. Monitoring ensures the sustainability of the process. An overall coordinator should be assigned to all the centers where testing is done so that the process can be easily monitored from time to time. Another job of the coordinator is to make appropriate and optimized route plans for the specimen collectors. This would make the process more capable and less time consuming. Response rate of recent five days are shown in table and figure:

Table 3: Comparison of calls in the hotline of IEDCR, Bangladesh and specimen collection

Date	Total Calls	Collected Samples
24 April, 2020	84590	3712
25 April, 2020	77437	3422
26 April, 2020	77109	3680
27 April, 2020	78218	4192
28 April, 2020	78187	4332

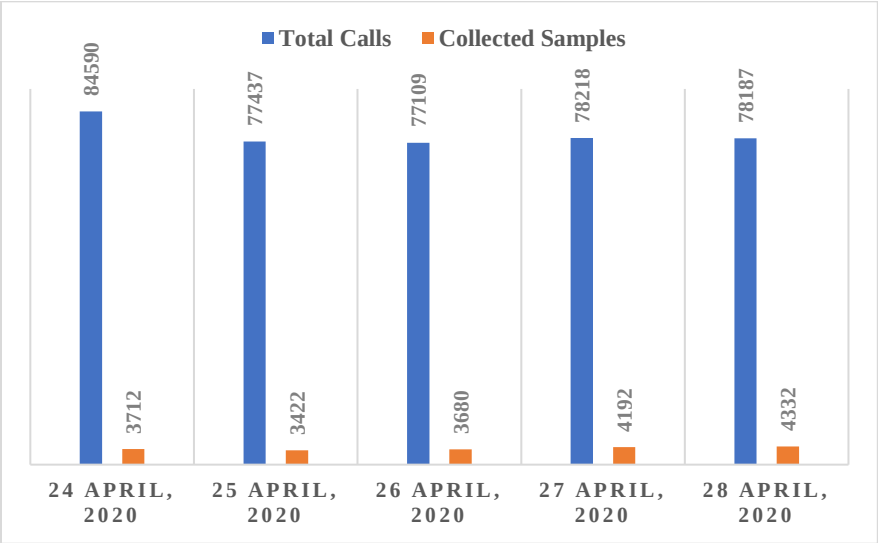

Figure 6: Comparison of calls in the hotline and specimen collection

4. Recommendation

For further research, it can be proposed, to study the relationship between lean six sigma practice (LP) and Supply Chain Innovation (SCI) in IEDCR, Bangladesh for epidemic healthcare management. Identifying the barriers for implementing lean six sigma for pandemic healthcare management can be an excellent approach for elimination of the potential barriers. Comparative study regarding the implementation of pooled testing for COVID-19 can also be carried out.

5. Conclusion

In order to successfully integrate the new process described, all the related personnel involved in the overall epidemic healthcare management system must believe in the solution. They must be capable of the continual monitoring of the process to ensure that improvement are maintained. Therefore, this study must help IEDCR authority, management of the dedicated hospitals and policy makers to find the best quality management approach to achieve their best performance in overall epidemic healthcare management during COVID-19 outbreak.

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Biographies

Aquib Irteza Reshad is a novice researcher and final year undergraduate student in the Department of Industrial & Production Engineering (IPE), BUET. His research interest includes operations research, supply chain management, total quality management, machine learning and data science.

Md. Mozibur Rahman is a novice researcher and final year undergraduate student in the Department of Industrial & Production Engineering (IPE), BUET. His research interest includes supply chain management, CAD/CAM, artificial intelligence, machine learning, probability and statistics.

Naquib Mahmud Chowdhury is a novice researcher and final year undergraduate student in the Department of Industrial & Production Engineering (IPE), BUET. His research interest includes manufacturing process, supply chain management, total quality management, artificial intelligence and machine learning.

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