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Application of VSM as a Lean Tool in a Healthcare Facility

M. A. Karim, M. A. H. Mithu, Tarequl Islam, Nayan Bhowal, Hadi Ahmed

Abstract: ***The healthcare industry can be termed as one of the most critical sectors of the economy. Healthcare industries are adopting lean management principles to maintain high-quality patient care, optimise workflow, and eliminate waste. Among the lean management tools, value stream mapping (VSM) is a key tool that uses a flowchart to depict, analyze, and improve the actions involved in the system. The study aims to model the system through value stream mapping to identify waste and non-value-adding activities in the processes, enabling the system to eliminate bottlenecks, constraints, and waste. Sylhet Women's Medical College Hospital is chosen to conduct the study. The necessary data are collected through interviews with employees and patients in both outdoor and indoor departments, as well as through direct observation and review of previous records. eVSM software is used for creating current and future value stream maps. The total waiting time, processing time, and lead time of the processes in the outdoor departments and diagnostic centres of the hospital are measured and improved over the existing system in the proposed model of the value stream map. Although the proposed model cannot be implemented, it is clear from this study that VSM can ensure smooth healthcare service and enhance performance.***

Keywords: ***Healthcare, Value Stream Mapping, eVSM software, Lean Manufacturing.***

I. INTRODUCTION

The history of lean in healthcare dates back only a few years. Lean originated from the Toyota Production System (TPS) manufacturing process [1]. Since the mid-1950s, Toyota has been well-known for its efficiency, quality, and employee involvement. Today, lean has become the standard for efficiency and excellence in the manufacturing industry.

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**Correspondence Author(s)*

M. A. Karim*, Assistant Professor, Department of Industrial and Production Engineering, Shahjalal University of Science and Technology, Sylhet-3114, Bangladesh. E-mail: karim-ipe@sust.edu, ORCHD ID: 0009-0007-7980-7235

M. A. H. Mithu, Department of Industrial & Production Engineering, Shahjalal University of Science and Technology (SUST), Sylhet, Bangladesh. E-mail: mithu-ipe@sust.edu, ORCHD ID: 0000-0002-1531-485X

Tarequl Islam, Department of Industrial & Production Engineering, Shahjalal University of Science and Technology (SUST), Sylhet, Bangladesh. E-mail: tareq.ipe.sust@gmail.com

Nayan Bhowal, Department of Industrial & Production Engineering, Shahjalal University of Science and Technology (SUST), Sylhet, Bangladesh. E-mail: nayanbhowal@gmail.com

Hadi Ahmed, Department of Industrial & Production Engineering, Shahjalal University of Science and Technology (SUST), Sylhet, Bangladesh. E-mail: hadiahamed3340@gmail.com

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However, in the last few years, the healthcare industry has succeeded in deploying lean principles to achieve quality in its operations and processes [2]. Nowadays, there is an increasing demand for healthcare services, which creates challenges for hospitals in terms of cost and efficiency. Thus, healthcare professionals in many countries around the world are struggling to provide competent and safe care while being pushed to optimize the use of resources [3, 4]. The importance of adopting lean principles in healthcare organizations has attracted the focus of several researchers to study the consequential benefits of lean application in healthcare. Tay [5]. attempted to investigate how organizations can systematically focus on flow efficiency by considering the role and value of redundancy in Lean improvement projects. The researcher found that redundancy plays a crucial role in enabling the achievement of the goals of lean improvement projects. Spagnol *et al* [6]. concluded that to deliver world-class healthcare in the face of constrained resources and greater demand, a long-term vision and world-class leadership should be developed to sustain the initiative and insert lean into the DNA of healthcare organizations. They also tried to focus on lean healthcare implementation and Toyota's rules to overcome barriers.

Radnor *et al.* [7] discussed four multi-level case studies of the implementation of lean in the NHS (National Health Service), UK. The work was vast. Their results showed that the application of specific tools, such as 'kaizen blitz' and 'rapid improvement events', tends to produce small-scale and localised productivity gains. They also identified two crucial breaches of the lean tenets that result from significant contextual differences between manufacturing and healthcare. A few years later, Schonberger [8] illustrated the approach to lean by drawing from a case study that showed that the keys to success including high rates of saving lives and lean healthcare in general, boil down to just five lean methodologies, each focused on quick response. At the same time, Narayanamurthy *et al.* [9] developed a lean readiness framework and an assessment methodology using fuzzy-based method to measure the readiness of healthcare institutions for implementing lean. Lean healthcare, when practised in this way, can be a continuous improvement tool to become a 'true expert' in the processes of healthcare, including patients/families, healthcare providers, and supporting staff [10-12]. Toussaint and Berry [13] tried to implement lean and presented six principles that constitute the essential dynamic of lean management: attitude of continuous improvement, value creation, unity of purpose, respect for front-line workers, visual tracking, and flexible regimentation.

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Therefore, it is found that lean manufacturing procedures, when properly implemented, help manufacturers boost quality and profits while significantly reducing inventory, downtime, expenses, and production cycles. As a result of minimising waste and reducing waiting times, lean management in healthcare facilities refers to a collection of operating philosophies and techniques that work to maximise value for both patients and the organisation.

Nowadays, a variety of lean tools are employed in the healthcare industry, including Kaizen, 5S, value stream mapping (VSM), Poka-Yoke, standardised work, and kanban systems. Among them, VSM is one of the most promising candidates in the service sector. It uses flowcharts to represent each stage of the process. By creating a visual representation of the current state and future state of the value stream, VSM enables organisations to identify areas of bottlenecks, opportunities for waste reduction, and opportunities for improvement. VSM is, therefore, a tool for improving workplace productivity that combines material processing steps with information flow and other crucial related data that identify waste, shorten process cycle times, and implement process improvements. As VSM has been used in the manufacturing sector for many years, it is currently considered a key tool for implementing lean in healthcare systems [14-16].

This study investigates the impact of using VSM as a lean tool in the context of Bangladesh on healthcare systems. Additionally, by utilising lean principles and procedures to create healthcare organisations that are more patient-centred in their decision-making and processes. It should be ensured that all staff members, including clinicians, nurses, physicians, and administrative staff, can participate in identifying and eliminating areas of waste and inefficiency. Therefore, the main objectives of this study are to develop a current state value stream mapping model to identify and eliminate waiting time, admission time, collection time, patient journey time, scheduling time, and to identify avoidable and reducible process steps and non-value adding activities by suggesting a proposed future state model of VSM and reduced lead time to increase profitability.

II. STYDY DESIGN AND METHODOLOGY

This study focused on conducting research at Sylhet Women's Medical College Hospital, involving a thorough investigation and analysis of the complex healthcare system. The specific areas for investigation are selected, and data sheets are prepared to collect necessary information through direct observation and discussions with doctors, nurses, patients, and other stakeholders. To gain insight into the current state of facilities and process steps, the system was observed directly to identify value-added and non-value-added activities and steps, as well as unavoidable and reducible waiting times, queuing systems, and information and service flow routes. The information gathered is used to create a current state value stream map, which helps to identify bottlenecks, constraints, and waste in each process step. The calculated values include the total waiting time, lead time, and process time of the current system, as well as the flow percentage and route traversals for each route in the current state value stream mapping. After preparing the current state map, the hospital was visited to discuss the accuracy and credibility of the current state VSM model with subject matter experts.

After analysing the entire system using the current state VSM, remedial actions are proposed to address various variables and constraints, identify areas for improvement, and reduce non-value-adding activities. The data were input into VSM software, and the total waiting time, lead time, and process time of the proposed model were calculated and compared with the current state map. The scenarios have been developed to enable the system to eliminate various wastes and constraints. The performance of the proposed VSM models and simulations was compared to the current state model, and improvement strategies were suggested. 'Quick transactional pro' type eVSM modelling software is used in this study. Microsoft Excel is used to display the various trends of changing variables over time.

III. DATA ANALYSIS AND RESULTS

Process engineering principles suggest that 30 measurements are sufficient for process evaluation to establish statistical significance. So, 30 measurements were performed for each data point. As the whole system is complex, the proper areas to be investigated are selected from the patient's perspective. These areas were chosen because they have challenging goals in providing value to customers and increasing clinical productivity. These areas include: indoor departments and emergency services, the admission counter and account desk, outdoor departments, the pathology lab, and the diagnostic centre. The number of incoming patients at outdoor departments is collected after a thirty-day observation period. The average number of incoming patients at various outdoor departments is shown in Fig. 1.

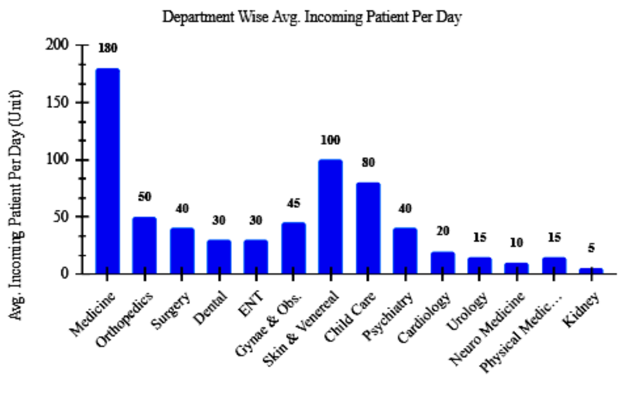

Fig. 1. Average Number of Incoming Patients In Outdoor Departments.

For creating the current state map, the summarised data collected by observing current facilities and process steps is used. Firstly, it is essential to identify who is making requests and who is providing particular services. Then, the steps required for getting the service are identified, which helps in identifying the issues and constraints.

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In this study, eVSM software is used for mapping the value stream of the healthcare system. The eVSM module was a 'quick transactional pro'. The current state value stream mapping was created separately to avoid complexity. Thus, the current state of VSM contains-

1. VSM of outdoor departments
2. VSM diagnostic centre and pathology lab

To receive the service, patients must be prescribed it by their doctors. Thus, the outdoor VSM contains the following steps-

1. Waiting in the queue at the outdoor ticket counter.
2. Name registration and ticket collection.
3. Waiting in the waiting room.
4. Consultation by a Residential surgeon or Professors at the specific outdoor departments.

According to the number of incoming patients, five departments were selected for the creation of the VSM. These include the Medicine, Orthopaedics, Surgery, ENT, and Gynaecology departments. The processing time, lead time, waiting time in each server, the number of resources in each server, the number of on-duty doctors in the selected departments, and the average number of incoming patients per day are the basic inputs required to create the model in eVSM software. The current VSM of these outdoor departments are illustrated in Fig. 2.

Statistical data, such as lead time, waiting time, and route utilisation, can be recorded and used to create reports in eVSM. eVSM is integrated with Microsoft technologies. It includes Visual Basic for Applications, allowing models to be further automated if specific algorithms are required. It also supports importing Microsoft Visio flowcharts, as well as reading from or sending output to Excel spreadsheets and Access databases. It performs some manual calculations and displays the outputs after the model run is complete. The production of the outdoor eVSM is illustrated in Table I for an incoming 350 patients per day.

Table I: Output of the Outdoor VSM

Route	Route Name	Route %	Longest lead time (Minutes)	Total Wait (Hr.)	Total processing time (Hr.)	Processing time (%)
1	Medicine	49.60	37.20	0.62	0.15	24.32
3	Gyne and Obs.	14.80	27.00	0.45	0.20	44.44
2	Orthopedics	14.80	25.80	0.43	0.17	38.46
5	ENT	10.40	21.00	0.35	0.12	33.33
4	Surgery	10.40	31.20	0.52	0.20	38.71
Average		100.00	31.80	0.53	0.16	31.83

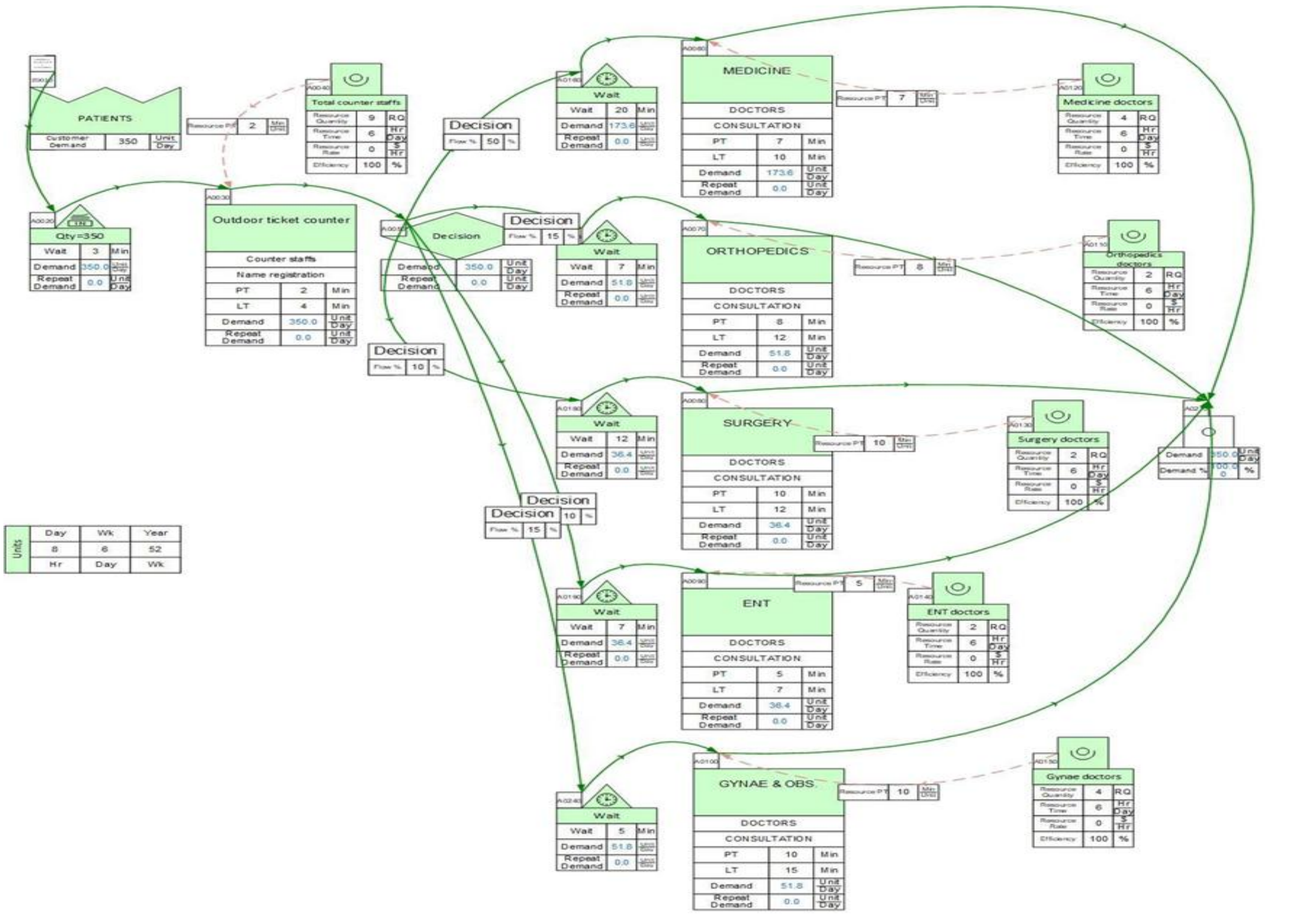

Fig. 2 VSM of Outdoor Departments

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The VSM of the diagnostic centre and pathology lab includes the following processing steps-

1. Doctor's consultation: indoors or outdoors.
2. Prescribing the required test by the doctors.
3. Making the payment at the reception counter of the diagnostic centre.
4. Deciding the type of diagnosis.
5. Execution of X-ray, ultrasound, or echocardiogram (ECG).
6. Sample collection from the patients, such as blood or urine.
7. Analyzing the batches of samples by the analyzer machines.
   Preparing the necessary reports by the consultants.
8. Review the reports by the pathologists.
9. Delivering the report from the reception counter.

The output of the diagnostic centre and pathology lab eVSM is illustrated in Table II.

Table II: Output of Diagnostic Centre and Pathology Lab VSM

Route	Route Name	Route %	Longest lead time (Minutes)	Total Wait (Hr.)	Total processing time (Hr.)	Processing time (%)
1	Pathology test	49.20	0.32	7.80	0.68	8.80
2	Ultrasound	20.00	0.03	0.75	0.23	31.00
3	X-Ray	15.60	0.04	0.92	0.33	36.00
4	ECG	15.20	0.03	0.75	0.25	33.00
1	Pathology test	49.20	0.32	7.80	0.68	8.80
Average		100.00	0.18	4.22	0.47	21.30

The models are validated with real-time collected data. After creating the maps, a discussion was held with subject matter experts, doctors, and staff to determine whether the models accurately reflect the current state of the existing system. Additionally, they are asked whether something is left or needs to be added to complete the model.

A. Evaluation of Types of Waste

VSM helps identify waste throughout the entire area under investigation. The exterior of the hospital and the diagnostic centre were modelled using VSM to identify non-value-adding activities and waste. There are seven types of waste in lean management. These are conveyance, motion, waiting, over-processing, inventory, defects, and overproduction. Wastes are identified in the current state of VSM so that they can be easily eliminated or reduced during the improvement phase. In the outdoors, the number of seats in the waiting room was inadequate to serve the patients. It was found that the doctors were not present at the scheduled time, resulting in a longer waiting period. At the outdoor ticket counter, there were four counter staff. It was adequate, but when patients came in large numbers, they were unable to provide a queue-less service.

In the diagnostic centre, the doctors who prescribed the tests were sometimes unavailable, resulting in longer waiting times. The patient's data was not organized and coordinated across various departments. The number of staff at the diagnostic reception counter was insufficient, which sometimes resulted in long queues in front of the counter. Wastes were generated due to the inefficient flow of information during the sample collection process. The conventional process of sample collection accumulates a significant amount of time. The number of collectors was insufficient in some cases. There were long queues for tests in front of machines such as X-rays, Ultrasounds, and CT scans, due to machine breakdowns and resource limitations. The number of pathologists and technologists was insufficient compared to the patient demand. Due to the absence of staff, it was found that report review and delivery were taking an extended period of time.

B. Future State Value Stream Mapping

Two current state value stream maps were created from the collected data. These two VSM models can help identify various constraints and issues affecting process performance. Based on the recommendations from the eVSM software, two future-state maps are proposed.

a. Future State Map for Outdoor

The future state map is proposed by reducing and avoiding non-value-adding waiting time in the current system. Most non-value-adding activities can be avoided by increasing the number of servers. The current resources are inadequate to serve incoming patients. When the

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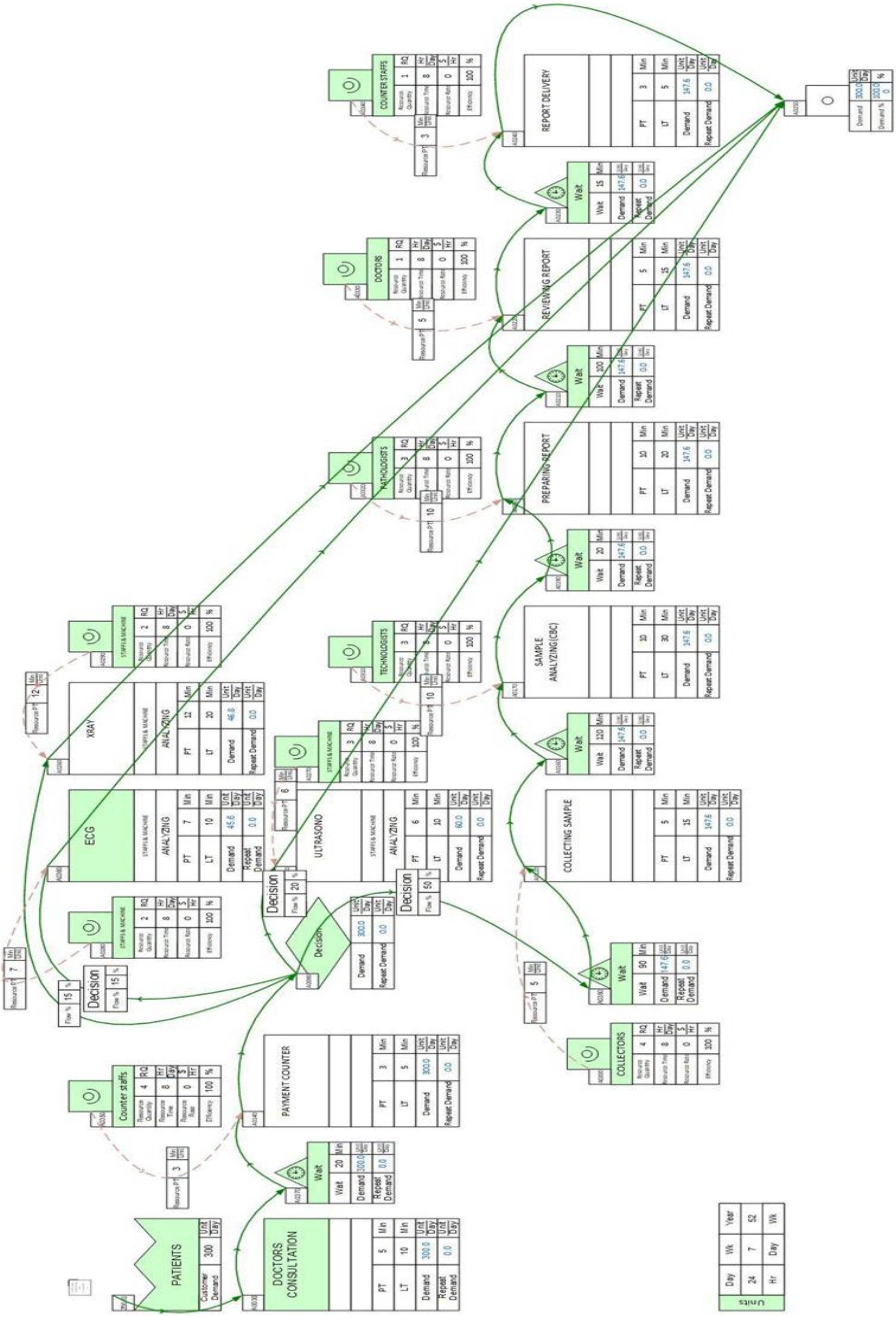

Fig. 3. VSM Model of Diagnostic Centre & Pathology Lab

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As the number of servers increases, patients will experience smoother service, and the flow will improve. The non-value-adding average waiting time per patient, which can be reduced by balancing resources and servers at each waiting point, was taken into consideration in the future state map based on the suggestions of the eVSM software, as illustrated in Fig. 3. The non-value-adding waiting time per patient in each department is summarised in Table III.

Table III: Name of the Table That Justifies the Values.

Activities	Non-value adding average waiting time (min)	Type
Medicine	20	Avoidable
Orthopedics	7	Avoidable
Surgery	12	Avoidable
ENT	7	Avoidable
Gynecology	5	Avoidable

Additional servers and resources required to minimise waiting time, as suggested by the eVSM software, are listed in Table IV.

Table IV: Resource Comparison at Each Server in the Indoor Department, Existing and Proposed VSM Models.

Resource Type	Current State Map	Future State Map
Total counter staff	9	11
Orthopedics doctors	2	5
Medicine doctors	4	10
Surgery doctors	2	5
ENT doctors	2	3
Gynecology doctors	4	7

The output of the future state map of outdoor VSM is summarized in Table V.

Table V: Output of the Proposed Model of Outdoor VSM.

Route	Route Name	Route %	Longest lead time (Minutes)	Total Wait (Hr.)	Total processing time (Hr.)	Processing time (%)
1	Medicine	49.60	13.98	0.23	0.15	64.37
3	Gynecology	15.20	19.02	0.32	0.20	63.09
2	Orthopedics	14.80	16.02	0.27	0.17	62.54
5	ENT	10.40	10.98	0.18	0.12	63.90
4	Surgery	10.00	16.02	0.27	0.20	74.90
Average		100.00	15.00	0.25	0.16	64.00

b. Future state map for diagnostic centre and lab

The non-value-adding waiting time is summarized in Table VI.

Table VI. Waiting Time at Each Server for Patients at Diagnostic Centres and Pathology Labs.

Activities	Non-value adding average waiting time (min)	Type
Payment counter	20	Avoidable
Collecting sample	90	Avoidable
Sample analyzing	120	Avoidable
Preparing report	20	Avoidable
Reviewing report	100	Avoidable
Report delivery	15	Avoidable

Additional servers and resources required to fulfil all requirements, based on suggestions from the eVSM software, are plotted in Table VII. The outputs are summarized in Table VIII.

Table VII. Resource Comparison at Each Server at the Diagnostic Centre and Pathology Lab: Existing and Proposed VSM Models.

Resource Type	Current State Map	Future State Map
Staffs & machine_ultrasound	3	6
Staffs & machine_ECG	2	5
Staffs & machine_X-Ray	2	9
Collectors_collecting sample	4	10
Technologists_sample analyzing	3	12
Pathologists_preparing report	3	7
Doctors_reviewing report	1	7
Counter staff_report delivery	1	3
Counter staff_payment counter	4	8

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Table VIII. Output of the Diagnostic Centre VSM

Route	Route Name	Route %	Longest lead time (Minutes)	Total Wait (Hr.)	Total processing time (Hr.)	Processing time (%)
1	Pathology test	48.80	0.07	1.67	0.68	41.00
2	Ultrasound	20.40	0.02	0.42	0.23	56.00
3	X-Ray	16.00	0.02	0.58	0.33	57.00
4	ECG	14.80	0.02	0.42	0.25	60.00
Average		100.00	15.00	0.25	0.16	64.00

IV. FINDINGS OF THE STUDY

The following formula is used to find the output (Table IX) and the result of the existing and proposed VSM models of indoor departments and diagnostic centres based on resource balancing in each server:

$$\text{value-added percentage} = \frac{\text{Value added time}}{\text{Total time}}$$

Table IX. Result of the Existing and Proposed VSM Models of Healthcare Facilities

VSM Model	Value added time (hour)	Total time (hours)	Value added (%)
Current state of outdoor VSM	0.16	0.53	30.19%
Proposed future state of outdoor VSM	0.16	0.25	64.00%
Current state of the diagnostic centre VSM	0.47	4.22	11.14%
Future state of diagnostic centre VSM	0.47	1.05	44.76%

V. DISCUSSION

This study highlights the significance of a single lean tool, known as VSM. There are many other lean tools, besides the VSM, that can be implemented in healthcare, such as kaizen, 5s, and visual control. This study does not discuss the significance of these findings. Many clinics and hospitals are not suitable for implementing Lean tools and techniques. Additionally, the costs associated with the increased resources in the proposed model were not factored into the analysis. The developed models sometimes fail to represent the actual system accurately. Some of the collected data was obtained by assuming and consulting with subject matter experts. The results of the VSM modelling would have been more accurate if the data had been collected over a longer period and with greater accuracy.

VI. CONCLUSION & FUTURE WORK

During this study, data were collected and system modelling was conducted. Although various wastes accumulate indoors, outdoors, and at the diagnostic centre, the authorities are not taking the necessary measures to reduce waste accumulation. The total waiting time was measured and improved in the proposed model over the existing system. The lead time for each route was determined, and the value-adding processing time was calculated to identify potential issues and constraints. The source of waste can be identified and eliminated. The study explores the concept of implementing lean tools and techniques within the healthcare system. The VSM and simulation modelling can also be implemented in various other service industries, such as banking systems, railway stations, and airports. Further studies can be conducted in multiple departments, hospitals, clinics, and medical facilities.

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Ethical Approval and Consent to Participate	No, the article does not require ethical approval or consent to participate, as it presents evidence that is not subject to interpretation.
Availability of Data and Materials	Not relevant.
Authors Contributions	All authors have equal participation in this article.

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AUTHORS PROFILE

M. A. Karim serves as an assistant professor in the Department of Industrial and Production Engineering at Shahjalal University of Science and Technology (SUST) in Sylhet, Bangladesh. He has over 12 years of academic experience and more than 2 years of research experience at FEV Motorentechnik GmbH. He earned his MSc in Energy Engineering from RWTH Aachen, Germany, and his BSc in Mechanical Engineering from the Bangladesh University of Engineering and Technology (BUET), Bangladesh. Currently, his research revolves around energy engineering, diesel and gasoline engines, human factors engineering, and lean manufacturing tools and techniques. Throughout his academic career, he has contributed to numerous international journals and conference publications.

M.A.H. **Mithu** is a Professor of Manufacturing Engineering in the Department of Industrial & Production Engineering, Shahjalal University of Science and Technology (SUST), Sylhet, Bangladesh. He received an M.Eng. in Manufacturing Engineering from the Bangladesh University of Engineering and Technology, Bangladesh, in 2006, and a PhD from the Department of Mechanical, Nuclear, and Production Engineering (DIMNP) at the University of Pisa, Italy, in 2011. His research interests lie in the domains of traditional and non-traditional manufacturing processes, environmentally conscious manufacturing, operations management, and Lean manufacturing tools & techniques. Currently, he is working in the field of electrochemical micromachining, specifically in the design, development, and fabrication of micromachining workcells, as well as the design and fabrication of microtools and their applications in practical fields. He has a substantial body of work, with numerous publications in international journals.

Tarequl Islam is an Industrial Engineer with working experience in Operations and Supply Chain in the RMG, FMCG and Packaging industries. Currently, he works as a Capacity Planner in the Supply Chain Department of Avery Dennison Bangladesh, a Fortune 500 company based in the USA. He holds a Bachelor's degree in Industrial and Production Engineering from the School of Applied Sciences and Technology at Shahjalal University of Science and Technology, Bangladesh. He aims to complete his PhD and continue as an academic while pursuing a career as a researcher in the future. His research interests include Human Factors Engineering, Ergonomics, Healthcare Systems, lean techniques and tools, Supply Chain Management, and Advanced Manufacturing.

Nayan Bhowal is presently engaged in the pursuit of a Master's degree in Information Technology at King's Own Institute in Australia. He completed his undergraduate studies in the Department of Industrial and Production Engineering at Shahjalal University of Science and Technology in Bangladesh. After completing his B.Sc. degree, he worked as an industrial and production engineer at Esquire Knit Composite and Text World. Additionally, Nayan Bhowal registered his ANZSCO (skill level 1) as an Australian engineering technologist from Engineers Australia (EA). He is currently employed at JD Sports Australia as a warehouse assistant in the supply chain department. Nayan's areas of research focus encompass Data Science, machine learning, and distribution strategy automation.

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Hadi Ahamed, a dynamic professional with a background in Industrial and Production Engineering, is currently making significant strides in the realm of quality management at Walton Hi-Tech Industries PLC, one of the prominent electronics giants in Bangladesh. In his capacity as a Quality Engineer, Hadi leverages his extensive expertise to elevate product quality standards within this prominent technology company. Armed with a bachelor's degree in Industrial and Production Engineering, he possesses a robust knowledge base in streamlined production processes and methodologies for quality control. His professional passions centre on ensuring quality assurance, optimising processes, and staying current with technological advancements in the field of industrial engineering.

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