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Article

Operational Process Improvement for Outpatient Services at a Private Medium-Sized Hospital

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Abstract. This study is dedicated to enhancing the efficiency and efficacy of a medium-sized community hospital's services, which have limited space and experience a high volume of visits from diverse patient types with distinct service processes. The hospital challenges meeting the waiting time Key Performance Indicator (KPI) primarily from internal factors. The research methodology involves a comprehensive approach, encompassing the collection of qualitative and quantitative data, interviews with hospital staff, on-site observations, and a detailed examination of processing times at each step within the outpatient department. Upon data analysis, the study identifies and categorises key issues within the current Outpatient Department (OPD). These issues are encapsulated in three main categories, i.e., the unavailability of doctors during critical periods, insufficient staff for document delivery, and ineffective communication. Addressing the imperative of minimising patient system dwell time, a key competitive objective in the healthcare sector, this article is dedicated to identifying and implementing tools within a Lean framework. Tools such as root cause analysis, Poka-Yoke, and visual control are identified and implemented to optimise outpatient operations. Using simulation software, quantitative data is utilised to simulate and evaluate the outpatient process. The simulation results underscore significant periods during which doctors are absent, and an imbalance in workforce distribution emerges as a bottleneck. From a Lean perspective, recommendations are formulated to address these issues, emphasising the need for schedule balancing and minimising batch size through a proposed document method. The efficacy of these recommendations is subsequently validated using the simulation models. Through a series of optimisations and experiments, the average time in the system of social security patients has demonstrated a noteworthy reduction from 1,999 seconds to 1,820 seconds, reflecting an 8% improvement.

Keywords: Healthcare, process improvement, simulation modelling, visual management, Lean.

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1. Introduction

1.1. Hospital Introduction

In 1977, Thailand only had a few private hospitals, most of which were in Bangkok. People generally had to go to government hospitals, where there was always congestion and a shortage of hospital beds. Although the service has been expanded all the time, in the later period, many more private hospitals have begun to invest, which can help alleviate the congestion of government hospitals to some extent. However, outside Bangkok and neighbouring provinces, few hospitals were built. People in the metropolitan area still have to travel to Bangkok for treatment because the provincial hospital has insufficient beds or is far away. The hospital's founders believe that they should start building some private hospitals in the areas mentioned above to have the opportunity to serve the local people in the same way as the private hospitals in the city centre.

The hospital is located between a shopping mall and a canal, leaving no space to expand the hospital. Furthermore, the number of people who come to the hospital's OPD is very high. According to the hospital record, the total OPD visits in September 2022 were 34,819, an average of 1,160 daily visits. Outpatient service is where most people receive services, especially the waiting area to see the doctor and the dispensing area, where more people are coming to receive service than at other points. Therefore, it is considered a critical point and needs to improve the service and prepare to serve more patients.

To reduce the number of congestion and facilitate patient service in a limited area. The hospital, therefore, has divided the outpatient department into three sections, distributed in different parts of the hospital. This paper will focus on the most visited OPD. After discussing with the OPD chief and executive, they both agree that OPD section 2, which consists of the Medicine Department (MED), Ophthalmologist, Oto-rhino-laryngologist and Obstetrician, requires optimisation of the most, and it is more feasible to modify.

1.2. Problem Statement

Problems in service quality have forced hospitals to focus more on increasing the efficiency and effectiveness of their services, with the critical goal being faster service times and reducing unnecessary procedures to satisfy patients with service quality.

The research hospital recently encountered difficulty in service time in the Outpatient department. They had set 4 KPIs related to the service time of OPD (Fig. 1).

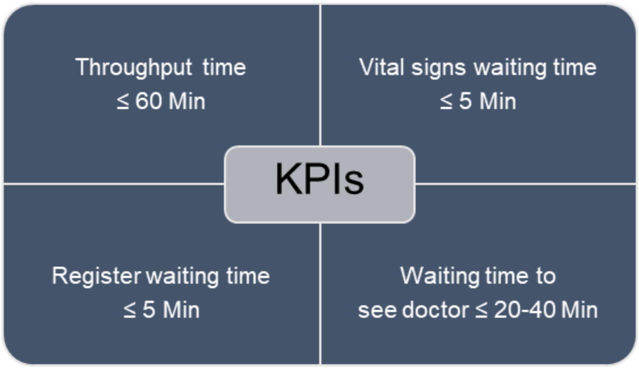

Fig. 1. Hospital KPIs.

According to the OPD chief, some service criteria did not meet the target set. Table 1 is the data on service waiting time collected between 17 to 21 October 2022. The red colour cell in the table mentions the criteria for which the waiting time exceeds the KPIs. From the preliminary observation and talking with the staff, the problems might be divided into two issues. The first problem is the space limit. Compared to other hospitals with more daily visits, the area is relatively small, which may affect patient service continuity. Furthermore, patients waiting for examinations and the finished ones need to sit together, resulting in a space that overlaps and the congestion of both the front of the examination room and the finance department in the same area. The second problem is the service design. As mentioned above, the hospital has 3 OPD sections, each with its register table and vital signs zone, and the processes are different in each OPD. There are slight differences in shift and staff utilisation design, and the process is relatively complex.

Combining the two main issues above will lead to the hospital executive and management team finding it somewhat hard to design the process and utilise the staff in the hospital and doctors' shifts to meet patient demand. Therefore, the hospital wishes to find out the root of the current problem, reduce wastage from using services according to patient perception, and continuously improve quality to achieve efficiency and effectiveness for the hospital service.

1.3. Research Objective

The research aims to improve the hospital's operating process through Hospital Lean Management.

Table 1. Hospital data collection.

Outpatient department	2						
Emergency Severity Index(ESI)	3	5	4	5	4	4	
Register waiting time (Min)	4.20	22.13	1.29	0.59	1.47	3.00	
Vital sign waiting time (Min)	4.22	0	0	0.00	0.00	0.00	
Diagnosis waiting time (Min)	8.52	127.51	14.17	66.41	14.37	46.58	
Throughput time (Min)	65	172	49	101	37	73	

(Source: Services waiting time collected by researchers in October 2022)

The scope of the research is to improve the operational process of the outpatient department by analysis of hospital process design, staff utilisation, and hospital floor design. Collect the related data in the OPD, identify the cause of the problem through an appropriate approach, and design a new process for the hospital, using the knowledge or ideas from relevant literature and case studies. Create the simulation of the new operation process and compare it to the old design to prove such improvements benefit the hospital by handing out as many scenarios as possible. Which will contribute to helping to detect all main issues affecting the service time in the outpatient department and reduce the bottleneck of the waiting queue in the outpatient service process.

The subsequent sections are as follows. Section 2 offers a literature review on tools and techniques. Section 3 outlines the research methodology of this paper. Then, Section 4 delves into the presentation of the data collection, interview results, and problem summary, while Section 5 shows how the outpatient department simulation model is formed. The analysis results are unveiled in Section 6, with the proposal for each problem discovered paving the way for the conclusions in Section 7.

2. Literature Survey

2.1. Problem Identification and Optimisation

Both public and private hospitals face competition due to social and economic conditions, and part of their ability to compete is to satisfy the patients who receive them. Hospital Lean is one of the knowledge that can be used to optimise the hospital's operating process. Maimoon et al. [1] used a time and motion study to identify a 'normal' or average time for work by utilising observers to record how much time is committed to each task. Summarised a circumstance that caused a delay in providing services on time, using a Failure model effect Analysis to identify the single source of the increased waiting time (Table 2). Pandit et al. [2] investigated the defects in the OPD process that are causing patient dissatisfaction by creating a cause-and-effect diagram. Pandit pointed out eight reasons affecting OPD patient flow (Fig. 2).

Many researchers have adapted the Lean concept to the hospital management concept. A method that helps identify operational value by eliminating wastage, keeping practical activities uninterrupted, and making work processes more efficient. Curatolo [3] identified two primary reasons Lean is well-suited to hospital settings. Because Lean concepts are simple and powerful, hospital staff may easily understand and apply them. Another reason is that the Lean approach aims to reduce and eliminate all types of waste, a consistent problem in hospitals. Curatolo et al. summarised the literature study and presented the main techniques supporting the characteristic activities of business process improvement in hospital-based Lean approaches. Marsilio et al. [4] benchmarked Lean implementation, installation, and outcomes in health services via a survey. The Hospitals report outstanding patient satisfaction scores, significantly influencing patients, expenses, and service improvement.

However, not only is using Lean enough, but also using the capable tool and making the implementation last long is essential. Shortell et al. [5] performed a multivariate analysis, claiming that Higher Hospital Consumer Assessment of Healthcare Providers and Systems patient experience scores were connected with Lean hospital implementation. However, none of the other six out of ten performance indicators were related to the degree of Lean adoption. Lima et al. [6] research showed that many Lean implementation hospitals lack work in continuous improvement approaches. A well-designed, sustainable continuous improvement system that emphasises the value provided to patients and improves well-being among hospital personnel will likely significantly contribute to

Table 2. FMEA of hospital services [1].

Process	Potential failure model	Potential effects of failure	Severity	Potential causes of failure	Occurrence	Detection	RPN
Patient calls for appointment	Line busy	Pt gets frustrated	2	Understaffing	3	7	45
	Staff unaware of doctors	Staff not able to direct pt to doctor	4	Lack of communication between staffs	3	7	84
Appointment made	Wrong time given	Pt dissatisfied	5	Improper communication	3	7	105
Patient arrives without appointment	Doctor not available	Pt has to leave and return again	2	Pt without appointment	8	1	16
Vitals check	Repetition of tests	Pt gets irritated	6	Lack of coordination	2	3	36
Consultation	Delay in seeing doctor	Pt gets annoyed	8	Doctor seeing another patient	9	2	144
Investigations ordered	Delay in sample collection	Pt gets frustrated	5	Insufficient manpower	7	2	70
Reports collection	Delay in delivery of reports	Pt has to go and return again	4	Time taken to search the reports	6	5	120
Billing	Wrong billing	Loss of payment made	8	Improper communication	4	3	96

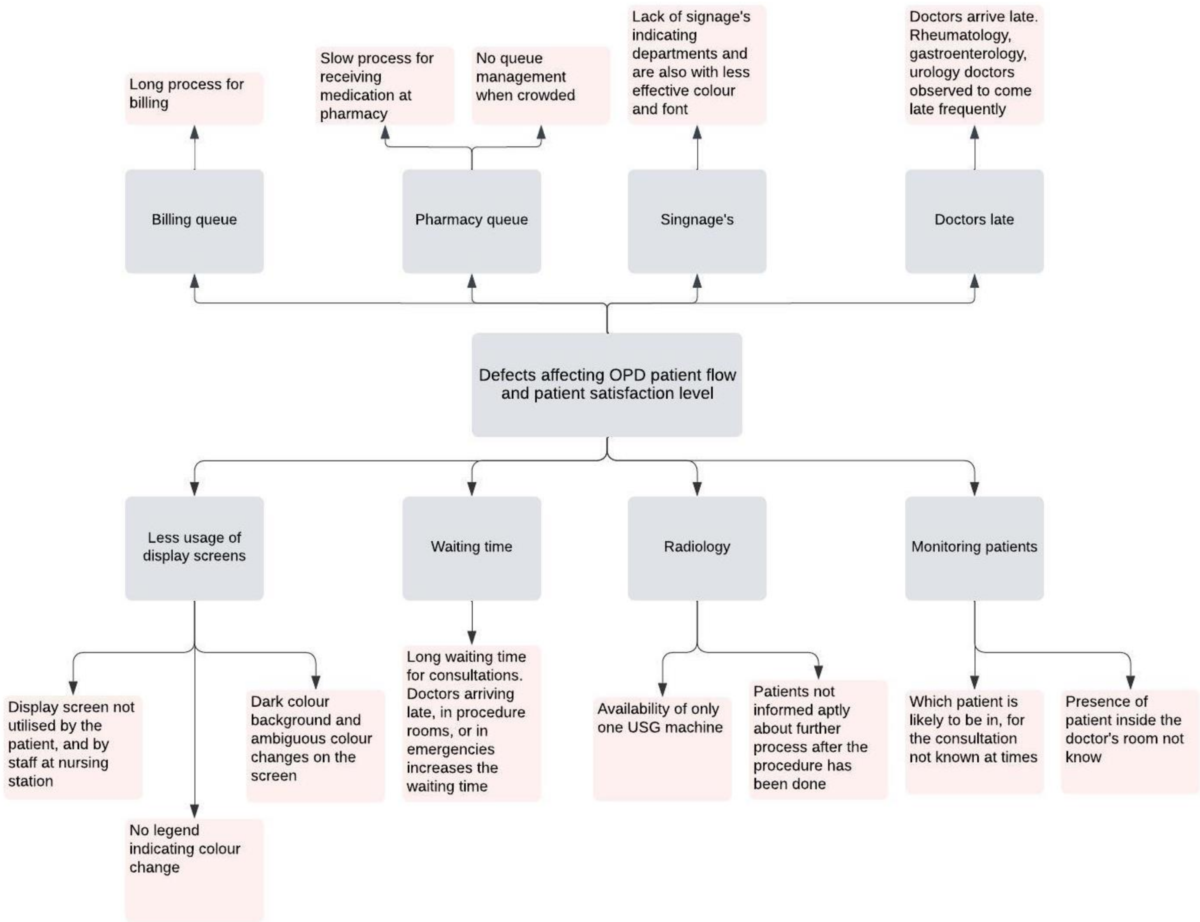

Fig. 2. Defects affecting OPD patient flow and patient satisfaction level [2].

society. Lean thinking can provide valuable insights for the improvement of Hospitals.

Intan et al. [7] research used a Lean Thinking approach, collecting quantitative data, identifying waste in the outpatient pharmaceutical service processes at the Hospital, and proposing specific strategies to reduce waiting times for finished drug service and concoction drugs, improving the quality and efficiency of healthcare services provided to patients. The study suggests numerous advice, such as changing the layout to reduce waiting time, increasing human resources, and optimising the use of technology in OPD. One medical error that generally happens in OPD is human and document error. Sanji et al. [8] used the Lean tool, Failure Modes and Effects Analysis, and fishbone diagram to identify and prioritise process errors and simplify and classify the sources of complicated problems in prescribing errors and prescription errors in the ENT outpatient department. The tool helped the author summarise the issue and develop a practical proposal.

Another controversial topic is Lean visual management. Graban [9] said that when standard objects are marked using visual approaches, it is clear when anything is missing. Instead of a blank spot, everyone can see an outline labelled with what should be in that place, which enables more proactive issue solutions. Visual management is an essential part of Lean healthcare and has two basic tenets: "First, make problems or status visible; and second, manage those situations, reacting as needed in the short term and solving root causes of those problems in the long term. The impact of visual communication can be defined as 5 min on the shop floor instead of 50 min of presentation (Iuga, [10]). Pereira (Pereira & Bittencourt, [11]) explained that Visual management enables a quick and easy understanding of the production area's status, making communication more effective and efficient. Ulhassan [12] used interviews, observations, and photos for a case study on two cardiology wards. The findings revealed that VM was well-received on one ward and increased continuous improvement efforts; however, it needed to fit better into the workflow and be sustained on the other. According to the study, VM can boost communication and cooperation.

Kovacevic et al. [13] described numerous successful cases of Lean implementations in healthcare environments and the results of the application (Fig. 3). By using four Lean tools, 5s, Kaizen, VSM, and Visual management, the hospital achieved some significant improvements, such as reduced lab test results reporting time to the patient and increased patient safety by implementing the Patient Safety Alert system. Reduced nurse walking distance, freeing up more than 250 hours of staff time spent walking for direct patient care.

Many researchers mentioned the challenge of Lean thinking, including differing viewpoints on its application and the challenge of providing consistent, high-quality treatment with limited resources (McCleanan & Young, [14]). Resistance to change, lack of leadership support

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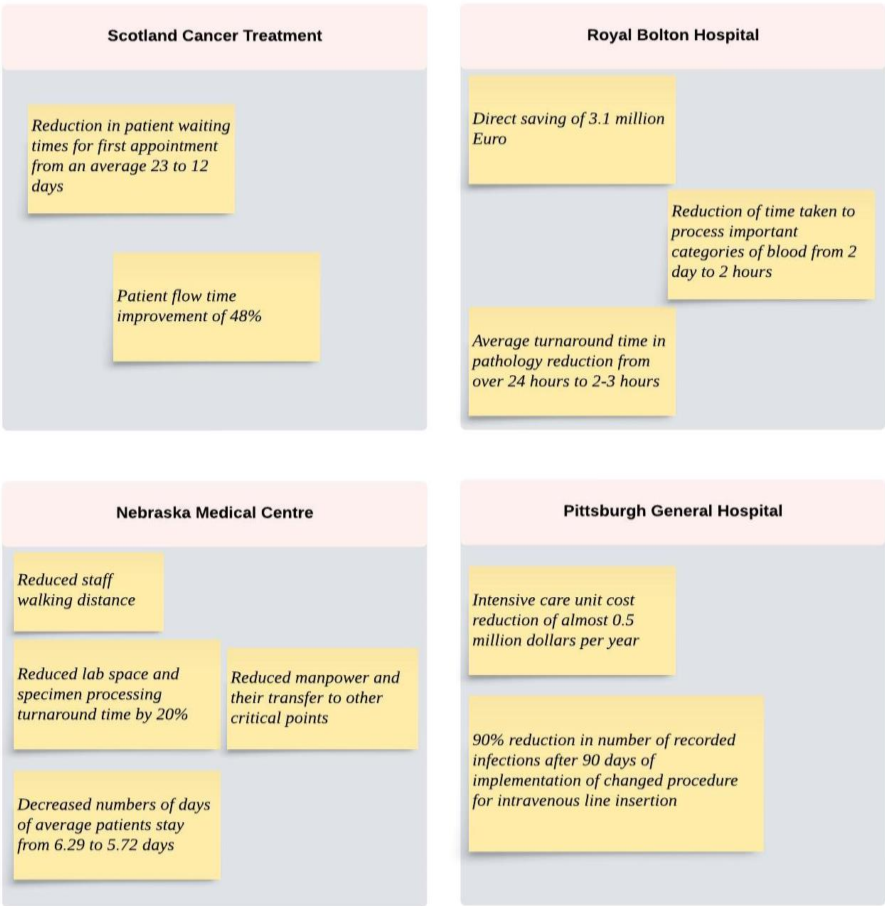

Fig. 3. Examples of successful Lean implementation in hospitals [13].

(Graban, [9]), and requires significant time and effort to achieve the desired results (Kovacevic et al.,[13]). It is critical to balance Lean concepts with a patient-centric focus. Patient outcomes and safety should always be prioritised in healthcare, and Lean improvements should improve patient care. Despite these obstacles, several hospitals have successfully implemented Lean concepts to enhance efficiency, patient care, and overall results. Strong leadership, a dedication to continuous improvement, and a flexible strategy for Lean implementation in the healthcare setting are required to address these issues.

2.2. Computer Simulation

Simulation is a collection of methods used to simulate real situations or system behaviour on a computer by using computer programs to help study the flow of activities in various organisations by collecting data and analysing the result from a computer program for future improvements. In actual practice, it is possible to experiment or modify the process until the benefits are seen, such as eliminating unforeseen problems that slow down the production process. Therefore, the simulation allows one to analyse the system's current state and help find a suitable approach or alternative scenario before applying it to an actual situation or practice.

Simulation-based analysis can help to identify potential issues and opportunities for improvement cost-effectively and efficiently; Borges [15] mentioned benefits of simulation modelling, such as compressed-time experimentation, easy demonstration, supporting the reduction of change resistance, cost reduction and lead time, and greater understanding of the processes among its stakeholders.

Duguay & Chetouane [16] studied a simulation of the emergency department waiting in line at Dumont Hospital Moncton, Canada, to reduce patient wait times and improve the overall service system. The system was enhanced by adding staff to work based on the relatively long average waiting times for patients. The study found that adding staff to work reduced the average waiting time of patients by a percentage point. 2.21.

Choi et al. [17] suggested a new simulation-based operation management method for outpatient operations. It comprises a simulation-based scheduling system and a business process management system. The simulation-based scheduling system gives the outpatient department future visibility in response to scheduling process invocations via simulations built using a formal modelling technique. Choi also pointed out that the simulation's benefit is minimising the patients' invisibility of waiting time and developing stakeholders' awareness of the outpatient operation time.

Arena is a widely used modelling tool that simulates an actual system on a computer to study the system's behaviour and lead to a more efficient approach to system

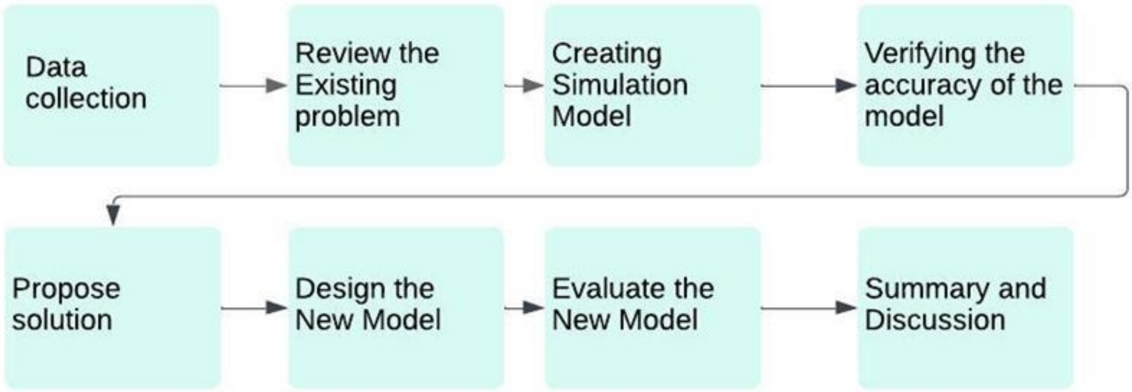

Fig. 4. Process flow of the research method.

improvement. Khlie & Abouabdellah [18] studied patients' service length in a Moroccan hospital from arrival to discharge to investigate problems that could affect their functioning, using Arena software to improve and develop the hospital's operating system.

Aliyu [19] simulated Doha Hospital clinic's eight alternative appointment systems to choose the approach that would decrease patients' waiting time in the doctor's queue, minimise the number of patients waiting in the line, and maximise the utilisation of the asset. Kulkarni et al. [20] examined patient flow and concerns with waiting time and service time in various departments, using Arena to help identify the bottleneck spot that the billing and OBG areas have longer wait times, and the resource usage was more remarkable in these parts. Therefore, the new resource optimisation model was introduced. Aziati and Hamdan [21] determined patient flow waiting times, which are used to improve operating performance and the quality of services provided to patients. Using descriptive-analytical and simulation methods to develop a suitable model resulted in the average waiting time of patients in the queue being 54.295 minutes, lower than the target of 60 minutes adopted by the Ministry of Health patient charter.

Another simulation program is SIMIO; Yuen & Hongtu [22] utilised SIMIO to validate their research on patient flow and bed capacity planning of Vancouver Coastal Health. The model assisted in answering problems such as the impact of installing protected surgical beds and releasing more patients from specific units. Consequently, it demonstrates that the simulation model was utilised to create findings that provided insights to support decision-making. Masmoudi et al. [23] constructed an emergency room model using SIMIO software to simulate numerous situations, altering one of its variables each time. The results of the various simulated scenarios reveal that changing the number of doctors can significantly impact the duration of patients' stay and the number of patients who leave the service.

In this Section, adopting the Lean concept in hospital operations is a viable method for addressing efficiency and quality. While there are limitations, successful application has been demonstrated in various healthcare settings. Simulation of hospital operations is a valuable tool for optimising healthcare processes, improving patient care, and increasing operational efficiency. Healthcare companies should prioritise reliable data gathering, model validation, and collaboration to employ simulation approaches successfully.

In contrast to existing literature that primarily focuses on applying Lean concepts for problem identification, defect summarisation, or case studies showcasing the effectiveness of Lean methodologies, this research represents a pioneering effort. It ventures into uncharted territory by meticulously examining and synergising various Lean concepts and tools to uncover the root causes behind long waiting times in the service process—particularly within the specific geographical context of a hospital's Outpatient Department (OPD). The study utilises a simulation tool to validate the accuracy of the analyses derived from the collected data and subsequently propose improvement ideas targeted at specific bottlenecks, ensuring that the outcomes are measurable and conducive to informed decision-making. This research goes beyond the conventional boundaries, broadening the scope and understanding within the field. The holistic approach adopted in incorporating Lean principles enhances the analysis's breadth and depth. Essentially, this study contributes a fresh perspective, an innovative methodology, and a more comprehensive analysis to the existing body of knowledge, marking a significant advancement in our understanding of Lean applications in healthcare service optimisation.

3. Research Methodology

This research is a descriptive study that collects data and analyses the solution. Determine the appropriate alternative to the hospital's outpatient service model. The flow of this research process is shown in Fig. 4.

1) Data connection

The data collection on the use of the services of patients who come to the outpatient department uses the data of the patients recorded by the hospital and a stopwatch to collect data during 08.00-20.00 business days. The data can be separated into quantitative (patient waiting time, service time of various sections) and qualitative data (interview).

2) Review the Existing problem

Review the collected data, identify the process step with a bottleneck, list the factors affecting the system's service flow, and summarise the problems that need to be solved.

3) Creating a Simulation Model

The collected data is used to design each parameter in the simulation, which defines the properties in each process to substitute values into the scenario model. The reason for choosing simulation as a tool is to prove that the bottlenecks found during the observation and interview are accurate and to ensure that the operation improvement solution works without creating a new problem or bottleneck.

The reason for choosing simulation over math models is that simulation models are well-suited for complex systems where interactions are intricate and complicated to express mathematically. Simulations can handle higher complexity and uncertainty, while the latter may struggle to represent complex, dynamic systems with numerous variables and interactions. Simulation can incorporate many factors and variables, allowing for a more realistic representation. However, the accuracy depends on the quality of data and algorithms used, and the result is shown as an average value, while the math model gives the absolute value. However, most importantly, the simulation allows experimentation without impacting the real system. Different scenarios can be tested, and the model's response observed, aiding in decision-making and strategy development, which is the aim of the research.

4) Verifying the accuracy of the model

Before the model of the created system can be used to simulate the scenarios of various service improvement approaches, it is necessary to verify its validity. Statistical methods will validate the simulation by comparing the data obtained from the existing system and the results obtained from the simulation.

5) Propose a solution

Propose an approach to solving the problems of the current operation by summarising the literature and seeking an appropriate approach to improve the current outpatient department's performance.

Observing other hospital outpatient departments and interviewing the person in charge of the department, understanding each hospital's approach to achieving better KPIs. Benchmarking the operation and the asset utilisation of research hospitals with higher ranking hospitals to design a better operation process.

6) Design the New Model

After suggesting an approach to improve the system, discuss the possibility with the person in charge of the department. Pick the acceptable approach to create a new simulation model by modifying it at various points.

7) Evaluate the New Model

Analyse and improve the system and compare the waiting time and asset utilisation between the current system and the system according to the improved approach. Then, using MATLAB to run the t-test to check for the significant change in the optimisation model.

8) Summary and Discussion

Summarise the new approaches and discuss the benefit the hospital will get if it adapts the recommended scenario model to practice. Conclude the answer to the research question and give recommendations for further study.

4. Result

4.1. OPD Detailed

The hospital's OPD consists of 13 examination rooms. Each room specialist is shown in Table 3.

Table 3. OPD doctor room detail.

Rooms 2 to 6	Internal medicine and Psychiatrist (MED)
Room 8	Ophthalmologist (EYE)
Room 10	Otolaryngologist (ENT)
Rooms 11 to 14	Obstetrician (OBG)
Rooms 15 to 16	Dermatologist and Internal medicine (SKN)

In the OPD process, when patients arrive at the entrance, they will go through screening and vital sign checking first before going to the front service desk, where their personal data and health coverage will be checked. After the check, patients who have a blood check or lab appointment will go to the lab room, while others will start queuing in front of each doctor's room. When the examination is finished, the patient will wait at the Financial or Pharmacy department for their health coverage.

The annual visit of the year 2022 is 146299 from the data provided by hospital, and the four main visitor types divided by health coverage type are:

- W type: Social Security patient, 72.82 %
- G type: Pay by cash patient, 13.09%
- S type: Social security + Life Insurance patient, 8.19%
- C type: Life Insurance + Pay by cash patient, 5.90 %

According to Fig. 5, the patient arrived between 9 a.m. and 10 a.m. The largest, with 14.15% of total visitors, the trend decreases to an off-peak period between 10 a.m. and 3 p.m. Moreover, they start rising to the day's second peak at 3 p.m. (the research period is set to 13 hours). After setting a research period, the up-to-date doctors' working schedules were gathered from the hospital, and each doctor had a specific ID. An example of a working schedule is shown in Table 4.

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Table 4. Room No.2 doctor shecdule.

<table>
<tr><th>Time slot</th><th>Monday</th><th>Tuesday</th><th>Wednesday</th><th>Thursday</th><th>Friday</th><th>Saturday</th><th>Sunday</th></tr>
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8.30-11.30</td></tr>
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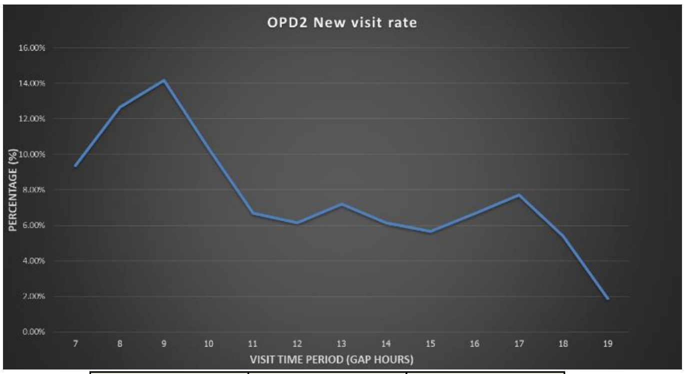

Time	Visitors	Percentage
7	13678	9.35%
8	18518	12.66%
9	20728	14.17%
10	15116	10.33%
11	9767	6.68%
12	9015	6.16%
13	10552	7.21%
14	8997	6.15%
15	8273	5.65%
16	9735	6.65%
17	11296	7.72%
18	7887	5.39%
19	2737	1.87%

Fig. 5. OPD visit rate in a day.

The hospital OPD-related area is shown in Fig 6. The floor plan is designed in the SIMIO program with a ratio of 1 grid per 0.6 meters, based on the 0.6*0.6 M tile OPD 2 used. The visitor's buffer zone or waiting zone is divided into four areas.

The first is the waiting area, used mainly by visitors waiting in front of the financial and pharmacy department after finishing all the examinations, with 31 seats in front of the counter and five in the hallway. The second area is in the middle of OPD, used by visitors waiting to register and waiting for doctor rooms 2 to 8. This area consists of 58 seats in a normal situation, and chairs can be added according to the hospital's peak period of the day. The third area, surrounded by rooms 8, 11, and 14, has 28 seats. Moreover, the last area is 31 meters from the register table where the venipuncture and doctor rooms 15 and 16 are located. The visitor waiting for X-ray and OPD3's financial and pharmacy department share the seats in this area. The estimated seats are around 22.

One of the research questions is to find the bottleneck of OPD through the whole service process and then prove that the bottleneck exists. Hence, the data collection is required to create a simulation model for observation. In this research, qualitative and quantitative are needed to prove the existing issues in the outpatient department.

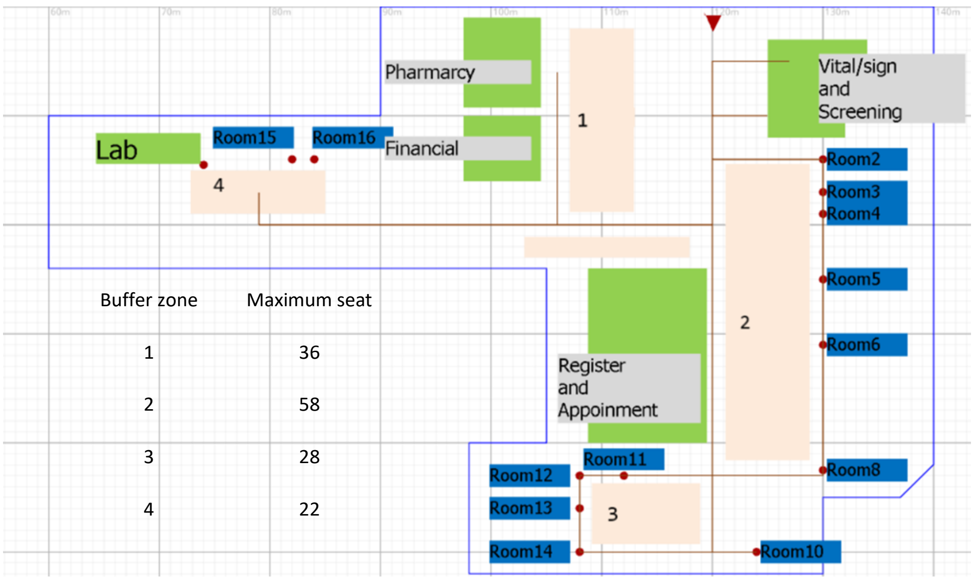

Fig. 6. OPD layout and buffer zone detail.

4.2. Qualitative Data Collection

Apart from doctors, hospital OPD staff can be branched into six main categories.

- Wecare: focus on serving patients who come by concentrating on non-W patients.
- Nurse: stand by in different locations such as screening, operation, and venipuncture rooms.
- Nurse: Stand by in different locations such as screening, operation, and venipuncture rooms.
- Front service: the register staff, the main activity is checking health coverage and preparing related documents for visitors.
- Financial staff: Collect money or a signed paper from the visitor on the front table, input the data, and print the related document.
- Pharmacy staff: consists of pharmacists and normal staff, prepare the medicine from doctors' prescriptions and handle them to the visitors.

The initial step to creating an effective purpose is understanding their current working process, situation, and bottleneck.

The interview was held between 25/1/2023 and 23/2/2023, comprising 13 interviews—one with the OPD chief and two for each staff team. Since every team has the rotation of working in different subtasks, there is no need to set a specific interview for every subtask in each staff team. The interviews were recorded by voice record with one interviewee per time. The interview questions table is shown in Table 5.

After all the interviews are done, the details of the four main points are summarised.

- Concern about the current process

Five out of six staff mentioned insufficient staff, some said they lacked a doctor, and some mentioned insufficient people to deliver visitor documents to the following process. The financial and pharmacy team suffered from the document's batch size; since the input data step of these departments has only 1 table, the batch size of the paper will increase the waiting time of visitors in specific periods. Some are concerned about the incorrect data passed to them since these cases will take time.

- Complaint issues

Before meeting the doctor, the main complaint issue was the long waiting time, where most of the interviewees agreed that the problem came from the doctor, who is unavailable for some reason when the queue is long. The other two issues are that the visitors needed to figure out what to do next and their status. After examination, the long waiting time complaint came from the prescription not arriving in the related department and missing or misplaced prescription.

- Main bottleneck

Apart from patients coming in early even if they have an appointment, which is an external issue, the internal bottleneck of OPD varies by the position and location where the interviewee worked. While the OPD chief said the bottleneck is at the vital sign and front service, others tended to say that the process before them is too slow, which causes the bottleneck, which affects them later.

- Improvement they need

Document going online is one of the ideas that most interviewees suggest since it will reduce the human error caused by writing and delivering the document, which the financial department said that they spent 10% of their working time fixing this error. Furthermore, some departments, such as pharmacists, can prepare before the document arrives. If they have an online prescription, they can save 50% of the preparation time compared with waiting for the prescriptions to be critical by their staff first.

Some staff want the patient's information checked immediately from the screening section. Able to explain to the patient on time whether or not they can use the

Table 5. Interview question for OPD staff.

OPD chief	
Background information	Can you describe the current working process of the whole OPD works?
Question regarding customer long waiting time	In your opinion, does the current hospital KPI related to waiting time validity?
	Has there been any complaint from the patient to you or OPD's Suggestion box directly about delayed service time?
	As the chief, in your opinion, what is the main bottleneck in service time?
	Has the hospital applied any change or adaptation to reduce customer waiting time?
	In your opinion, which section of the OPD needs the optimization most?
	If you could design the improvement by yourself, what would you do?
Question regarding the acceptance of the new change in the working process	What do you think about the change in the new floor plan, staff utilization plan, or process to improve customer satisfaction? (And what is the acceptable range of change?)
	Is there anything else you want to say about your current working environment or process?

OPD staff	
Background information on the interviewee	Can you describe the current working process of your work?
Question regarding customer long waiting time	Have there been any particular concerns or difficulties in the current working process and method? (Giving score from 1 to 10)
	Has there been any complaint from a patient to you or your co-worker directly about delayed service time? (If yes, ask for a brief story)
	In your opinion, what is the main bottleneck in service time?
	Has the hospital applied any change or adaptation to reduce customer waiting time? (If yes, ask for a brief story)
	If you could design the improvement by yourself, what would you do?
Question regarding the acceptance of the new change in the working process	What do you think about the change in the new floor plan, staff utilization plan, or process to improve customer satisfaction? (And what is the acceptable range of change?)
	If you could propose an improvement to management, what would it be?
	Is there anything else you want to say about your current working environment or process?

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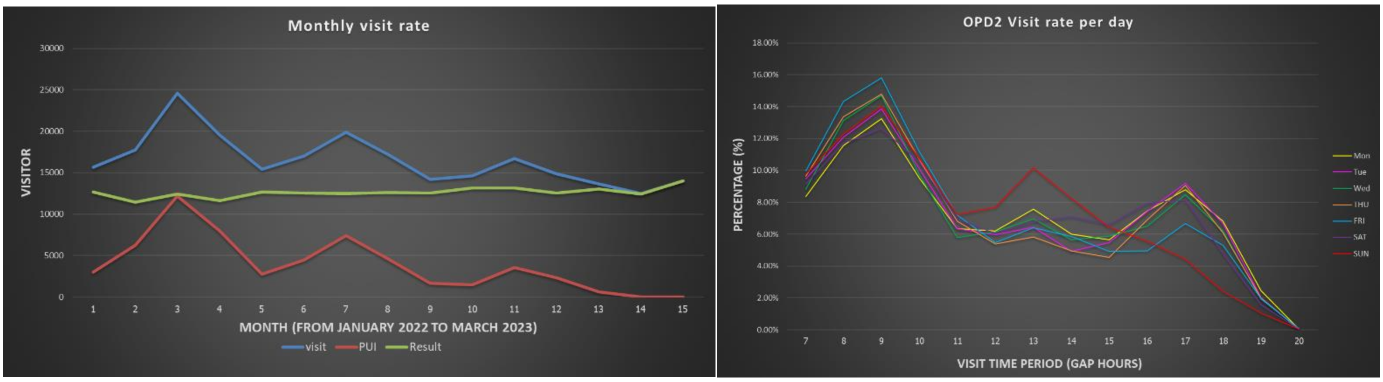

Fig. 7. Monthly visit rate and visit rate compares by date in a week of OPD.

insurance to cover the payment without affecting the time of other patients, reducing the burden of nurses and assistants. Increase communication quality between departments by providing a method to track the working process.

The main idea of current bottlenecks and improvement methods is created by interviewing each employee. However, with qualitative data alone, more is needed to develop the solution for the operation process. In the next section, quantitative data collection is conducted, where each accessible location is observed. Collected the numerical data needed for creating a simulation, which supports searching for the main issues that cause the long waiting time and is the support evidence for the hospital in adapting the optimised approach.

4.3. Qualitative Data Collection

Since OPD patients are included in various types of health coverage, the time each type of patient spends in some of the steps will be different, with full-time and part-time doctors in different specialists. Therefore, before the data collection starts, significance detection must be done.

From Fig. 7, there is no seasonal difference in the visit rate in each month, and there is no differential inpatient type on each day, as shown in Table 6. While in daily visit rate, the visit rate and number of patients on Monday to Friday follow the same trends, with the same peak time, while on Saturday and Sunday, the trends are different. Since the research aims to collect, analyse, create a model, and propose a solution for hospitals in business days, the analysis above shows that the visit rate and type of visitor are not affected by date.

In this process, the OPD is categorised into six sections related to the OPD working process and floor plan, which include:

- Vital sign/Screening
- Front service (Register)
- Financial
- Pharmacy
- Lab
- Doctor room (Examination)

Calculate the visit rate per day and use Box Plot to exclude the maximum and minimum observations, which happen on a national holiday in Thailand where the visit rate will fluctuate, such as New Year or religious holidays. The OPD average visit rate is 408. Then, calculate the sample size of each section, not including the doctor's room, because the hospital already records the data when patients enter and exit the room. Using the average of 408 per day, which is gained from the box plot, with a confidence level of 95% and an 8% margin of error, the sample size of 120 (rounded up from 110) for each day is set.

The data collected apart from doctor examination time will go through the following steps before analysis and use in simulation.

1) Delete an invalid number, such as a blank start or finish time.
2) Plot a first histogram to see the data group using the Rice rule to decide each doctor's data bin size.
3) Plot a box plot of each doctor and delete data that exceed the maximum and minimum observation.

Table 6. Visitor percentage by date.

Visitor by date Mon-Sun	Total visit (Year)	%
MON	21097	14.33%
TUE	20984	14.25%
WED	20522	13.94%
THU	20339	13.81%
FRI	20707	14.06%
SAT	20361	13.83%
SUN	23267	15.80%
Total	147227	100%
	W	G
Total	72.49%	11.72%
By date (Mon-Sun)	71.27% - 73.88%	10.75% - 13.05%

4) Put the number into Arena's input analyser, choosing the best-fit distribution, which gives a lower square error. The distribution in Arena consisted of Beta, Normal, Empirical Continuous, NSExpo, Empirical Discrete, Poisson, K-Erlang, Lognormal, Exponential, Triangular, Gamma, Uniform, Johnson, and Weibull.

4.3.1. Vital sign/Screening

In this section, the process takes place as follows:

1) Asking for symptom or appointment paper
2) Weighing, measuring height and blood pressure
3) giving the queue number

The collected data will be separated into morning and afternoon cases. Apart from the time start and finish recorded, the number of patients who must wait 15 minutes to re-check their blood pressure is collected.

This data is needed because the re-check patient influences the overall waiting time of another patient in the system, making the queue longer and the simulation more realistic. After creating a box plot and deleting the maximum and minimum observation, the data are put in Arena's input analysis, creating a histogram (Fig. 8) and distribution for vital sign checking time. From the total of 840 cases collected, the number of valid cases is 779 cases, and the re-check percentage is 23% (round up from 22.7%), with a mean of 43.8. The average time to prepare before the blood pressure check is around 20 seconds.

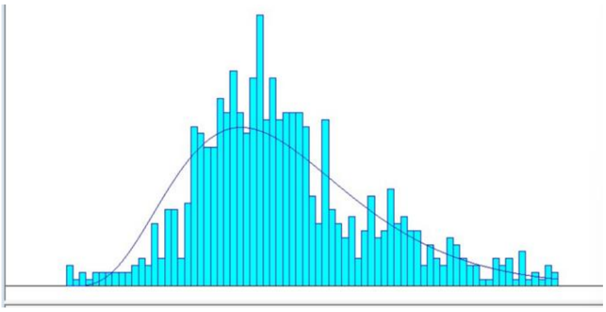

Fig. 8. Vital sign process time distribution from Arena's input analysis.

4.3.2. Front service

The front service process is as follows:

1) Check or create new medical records.
2) Confirm the appointment history and information with the patient.
3) Guiding patient through the following process (blood collection/X-Ray/ Doctor room)

Since each health coverage type required differences in process time at the counter, the data was required to be marked with the patient type. Apart from time recording, the front service staff is asked for cooperation in recording the type of health coverage and the patient who is guided to the lab before meeting the doctors since the patients who go to the lab are required to wait an average of one hour in the system. The average process time and distribution are shown in Table 7.

Table 7. Front service process time and distribution.

Type	Average time (s)	Distribution
W	30.08	5.5 + Erlang (8.19,3)
S and G	77.93	47 + 128*Beta (0.596,1.87)
C	33.41	18.5+52*Beta (0.93,2.19)
New/issues	170.84	114+421* Beta (0.438,1.94)

The percentage of patients sent to do the lab test is in Table 8.

Table 8. Percentage of visitors who need to visit the lab.

Time	Total case	Number of cases	percentage
Morning	1080	283	26%
Afternoon	949	108	11%

4.3.3. Financial

There are only three types of visitors that will enter the financial department process, which are types S, G, and C. Around 27% of visitors go through the above processes. So, the sample size is re-calculated from the non-W group only, with a confidence level of 95% and a margin of error of 5%. As a result, the sample size of 94 is set. The process inside the department is as follows:

1) Receive the document from the dispensary room.
2) Two support staff sit behind the counter, check for the details, and print out the related document.
3) Send the document to the front desk and a cashier, where two staff will confirm the details and ask the patient to pay or sign the paper.
4) If the visitors have medicines, the staff will guide them to wait at the pharmacy waiting zone, while visitors who do not have medicine will wait for an appointment card or leave.

The support staff at the back are asked to collect the processing time from when they received the paper until they pass the same visitor document to the front desk bucket. The front cashier staff is asked to collect the processing time from the visitor they called to arrive at the counter until they left. Both teams need to address the type of health coverage of visitors since each type requires different checking steps and document amounts. The average process time and distribution of the financial department are shown in Table 9.

4.3.4. Pharmacy

In this department, the process starts when the Nurse aid takes a prescription in front of the doctor's room and puts it in the basket of the sticker printing staff. The processes are as follows:

1) Pharmacy staff Input the data, print the sticker, and send the details to the Pharmacy room.
2) The Pharmacist team prepares the medicine.
3) Another Pharmacist team member pasted the sticker to the corrected bag.
4) Another Pharmacist team member checks before sending the medicine bucket to the front desk.
5) If the visitor is W type, two front desk staff can call the visitor, while for non-W type, the staff.
6) must send the paper to the financial department, which is located next to each other, and wait for the finance department's receipt before the call.
7) Confirm and give the medicine.

Table 9. Financial department average process time and distribution.

Location	Type	Average time (Sec)	Distribution
Cashier staff	S	53.3	8+Erlang (15.1,3)
	G	99	10+Weibull (98.9,1.92)
	C	89	17+Erlang (36,2)
Support Staff	S	97.4	18+159*Beta (3.04,3.05)
	G	43.4	6.5+Gamma (12.1,3.05)
	C	67.1	30.5+Weibull (40.6,1.69)

There are three main sections where the data needs to be collected.

- The first is the sticker staff, with only one staff member. Record when the staff pulls the prescription from the desk until the sticker is shipped.
- Second is the pharmacist team in the room behind, collected by the pharmacist team at the same period as the first step, starting the record when they receive the sticker and finishing when the medicines are shipped to the pharmacist.
- The last group is the pharmacist, who is responsible for describing the usage of medicine and giving them to visitors.

Table 10 shows the average process time and distribution of each step.

Table 10. The pharmacy department's average process time and distribution.

Location	Average time (Sec)	Distribution
Sticker printing	65.2	19+Gamma (19.1,2.42)
Medicine room	365	23+ Erlang (171,2)
Dispensing	84.4	21+ Erlang (31.7,2)

4.3.5. Lab

The lab tests include the process visitors must take before meeting the doctor, mainly consisting of blood tests and stool exams. The average process time is 103 seconds, and the distribution of 46+Erlang (28.7,2).

4.3.6. Doctor room

In the doctor room case, each room has its working schedule, and the doctor will have a personal ID, where the first letter is the room they mainly work in, and the last two-digit number is the number of doctors in that room starting from 11. In the doctor's examination time case, the data collection document was not used to collect the related data. However, instead, they used the raw data provided by the hospital between January to March of 2023. The data consisted of the patients entering the room time, exit time, and the doctors in the room during the period. Each doctor's calculation follows the same steps and rules as follows:

1) Delete an invalid number, such as not having to enter/exit time or doctor name.
2) Delete the time below 60 seconds from the hospital regulation that the patient must be served more than 1 minute. The lower number might come from a human error, such as forgetting to key an enter time when the patient exits; both enter and exit time will be the same time or a system error.
3) Plot a first histogram to see the data group using the Rice rule to decide each doctor's data bin size.
4) Delete the data bin lower than 5 % of the histogram data bin.
5) If the data point is lower than 50, search for a doctor with the same issues in the same speciality. Compare the data; if the trend is the same, combine the data.
6) Plot a box plot of each doctor and delete data that exceed the maximum and minimum observation.
7) Put the number into Arena's input analyser, choosing the best-fit distribution.

Table 11 shows the distribution of the doctors in the outpatient department.

Table 11. Doctor examination time distribution.

ID	AVG (Sec)	Distribution	ID	AVG (Sec)	Distribution
211	295	61+689*Beta (1.1,2.14)	1012	314	64+Gamma (114,2.19)
212	253	64+Erlang (63.1,3)	1013	402	86+806*Beta (1.2,1.86)
213	152	60+Weibull (91.0,0.992)	1014	455	61 + Weibull (425,1.39)
214	192	61+Weibull (141,1.33)	1015	450	75+Erlang (187,2)
215	214	60+Exponential (154)	1016	348	73+Weibull (304,1.66)
216	450	Triangular (61,232,1090)	1017	271	72+Exponential (199)
217	431	60+Weibull (394,1.22)	1018	271	72+Exponential (199)
218	192	61+Weibull (141,1.33)	1019	395	61+Weibull (346,1.12)
219	242	61+598*Beta (0.536,1.23)	1020	455	61 + Weibull (425,1.39)
220	232	60+Gamma (179,0.962)	1021	418	70+Gamma (160,2.17)
311	273	60+Erlang (107,2)	1111	650	62+Exponential (588)
312	1150	182+ Weibull (1070,1.75)	1112	471	64+Weibull (415,1.06)
313	150	60+320*Beta (0.745,1.91)	1113	423	61+Weibull (390,1.32)
314	575	Triangular (83,354,1290)	1114	545	Triangular (64,119,1450)
315	328	127+Weibull (203,1.03)	1115	682	63+1430*Beta (1.25,1.47)
316	695	104+Weibull (509,0.781)	1116	682	63+1430*Beta (1.25,1.47)
411	500	61+1160*Beta (1.1,1.79)	1117	682	63+1430*Beta (1.25,1.47)
412	384	61+Gamma (103,3.13)	1118	682	63+1620*Beta (1.12,1.82)
413	336	61+Weibull (303,1.59)	1119	795	69+Weibull (773,1.28)
414	418	Triangular (60,241,1020)	1120	651	60+1760*Beta (1.04,2.05)
511	284	61+Gamma (190,1.18)	1211	590	60+Gamma (504,1.05)
512	150	60+320*Beta (0.745,1.91)	1212	425	67+935*Beta (0.614.0.99)
513	461	Triangular (60,409,991)	1213	770	62+1960*Beta (1.06,1.89)
514	212	60+Weibull (167,1.7)	1214	770	62+1960*Beta (1.06,1.89)
515	208	61+480*Beta (0.847,1.91)	1215	770	62+1960*Beta (1.06,1.89)
516	131	60+300*Beta (0.37,1.2)	1216	448	63+Weibull (410,1.26)
517	354	61+ Erlang (73.3,4)	1311	464	60+Weibull (417,1.37)
611	342	61+Erlang (141,2)	1411	597	63+Weibull (576,1.33)
612	277	60+610*Beta (1.07,1.93)	1412	660	105+1260*Beta (1.33,1.7)
613	508	61+Weibull (474,1.25)	1413	484	Triangular (63,211,1180)
614	250	60+Weibull (197,1.13)	1414	484	Triangular (63,211,1180)
811	235	60+Exponential (175)	1511	413	61+818*Beta (0.938,1.24)
812	289	60+Exponential (229)	1512	358	60+889*Beta (0.948,1.88)
813	302	60+Exponential (242)	1513	276	61+Weibull (241,1.9)
814	225	61+554*Beta (0.825,1.92)	1514	313	Triangular (71,202,701)
815	275	60+Weibull (203,0.883)	1515	347	66+Weibull (304,1.37)
816	359	43 + Weibull (336, 1.26)	1516	466	Triangular (69,245,1090)
817	359	43 + Weibull (336, 1.26)	1517	466	Triangular (69,245,1090)
818	359	43 + Weibull (336, 1.26)	1611	311	Triangular (60,243,736)
819	359	43 + Weibull (336, 1.26)	1612	340	62+Erlang (92.5,3)
820	232	60+683*Beta (0.576,1.71)	1613	287	63+Weibull (249,1.67)
821	297	114+ Weibull (190,1.14)	1614	333	60+932*Beta (0.954,2.3)
1011	271	61+Gamma (117,1.8)			

4.4. Review the Existing Problem

By combining the issues from the interviews and onsite observation during the data collection period, three current problems occur in the daily routine of the outpatient department.

Problem 1: The doctor is unavailable during peak hours for an extended period

The OPD consisted of Walk-in and appointment patients. A patient can call to reserve the time and the follow-up case in the appointment case. The follow-up case doctor slot is already prepared, but the walk-in and appointment case sometimes requires the screening nurse to choose the available doctor for the patient. If the doctor leaves for an urgent, daily ward routine or rest, the patient who is assigned to that doctor must wait. When these cases stack up, it will lead to an increase in customer waiting time and complaints. As the interview results show, customers mainly complained to the nearby staff if they were waiting too long.

The schedule provided by the OPD chief provides basic information about the doctor responsible for daily emergency or ward consults, but the time was not specific; some slots are set for the same period as the doctor's working shift, such as 5 pm. to 8 pm. The nurse aid staff whose shift was in that doctor's room would be responsible for calling the doctor back to the room, and sometimes, the doctor is too busy to come down.

Problem 2: Work efficiency

Many cases of this issue mentioned insufficient staff focused only on one occupation, nurse aid. From the observation, the main problem is the efficiency of one staff member. Excluding the staff that stood by to support in the doctor's room, two groups of nurse aid were cursing the bottleneck.

The first group is the delivery of documents. As mentioned, when the examination is finished, the prescription and related documents will be put in a folder and stuck in front of the room. The free staff must move to collect and deliver the folder to the appointment desk and financial or pharmacy department, depending on the situation. In the vital sign spots, apart from the non-W cases that they had the Wecare team to support, another 72% of patient paper had to be delivered from the vital signs to the front service by nurse aid. Therefore, the paper, which the following process needs, sometimes comes in batches. Making the staff in another department's workload suddenly rise. It is evident in the pharmacy department in the sticker printing area that most of the documents came in batches around peak time, while only one person in the pharmacy responded to key data. At the same time, the stack of work will pass to the pharmacist and the financial department later. As a result, the waiting time in front of these steps increases.

Problem 3: Effectiveness of communication

The interviewee mentioned that the patient did not know what to do next; the staff did not know the internal document or doctor's situation to give hints about the observation location. While observing the daily routine of OPD, the patient's questions are passed through word of mouth between staff to the related department or counter to check, which affects the daily work time of some others.

Indeed, many of the patients did not visit for the first time. However, when new visitors or visitors have a language barrier, their progress status, such as where to go, the queue, or doctor status, should be visualised to support the acknowledgement. While the observation was ongoing, OPD had been adding a screen in front of the doctor's room, which showed the doctor's name, the queue number waiting, and the queue that waited for lab results. However, staff effectiveness and efficiency are also the improvement prospects for this research; the faster the work is done, there is no need to improve human resources, and the hospital can serve more visitors. Another mentioned was the error; it will take time to solve the problem and wastes more time than doing other essential jobs. There are few cases, but much time is wasted in checking and preparing the new document. Since hospitals aim to increase service rates and quality, staff should care for the patients instead of doing the paperwork.

5. Outpatient Department System Simulation

In this section, the simulation of the outpatient department will be created to support the argument and analysis of some problems stated to achieve the goal of the optimisation proposal. After analysing the existing problems and understanding the observation policy, the hospital will be simulated by SIMIO software.

SIMIO software is a new generation of full 3D system simulation software based on "smart object" technology developed by SimioLLC in 2004. Unlike other object-based simulation tools, SIMIO's objects are based on visual processes rather than code-based.

5.1. Model Introduction

Created outpatient department layout model and properties design and realised essential functions from the data gathered in Section 4. The layout of OPD is shown in Fig. 9.

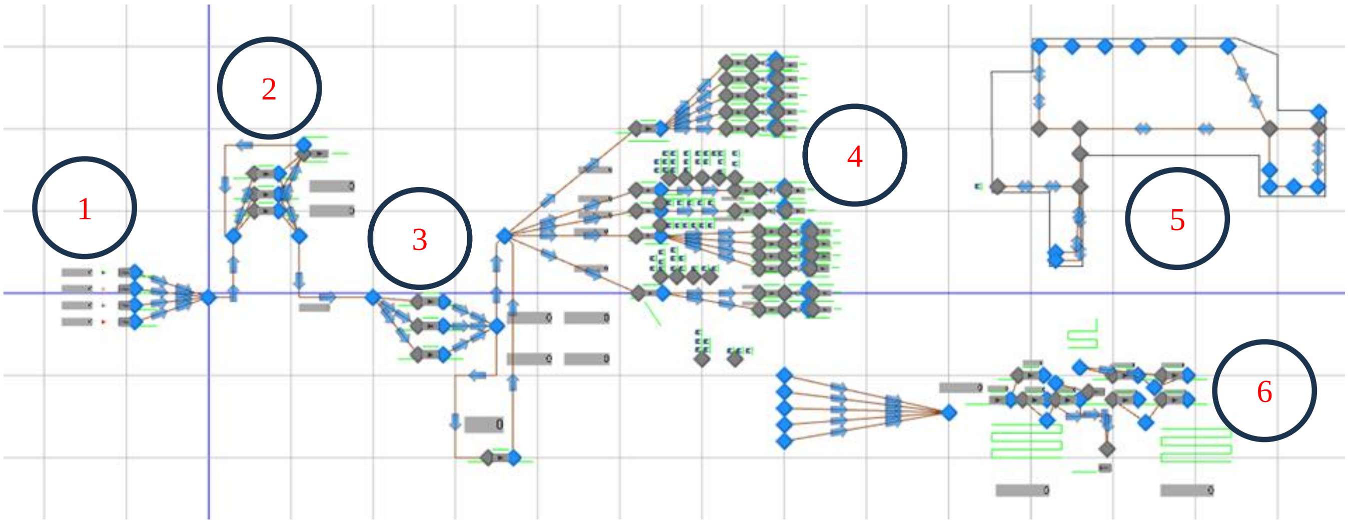

Fig. 9. Layout in SIMIO of outpatient department.

Point 1: This point is the entrance to the hospital. Several different data sets are built by referring to the hospital's data (average daily arrivals and patient types). The functions implemented include assigning a number to the Entity and its arrival time.

Point 2: The entities will enter the vital sign section (4.3.1) and have a probability of entering the re-check queue for 15 minutes.

Point 3: Enter the front service part (4.3.2) and allocate patients in the queue based on available tables. Then, the staff will read the patient type and assign the front service counter processing time (randomly through distribution). After leaving the front service, patients are sent to the examination room waiting area or to the lab based on probabilities from Table 8. Patients who are sent to the laboratory and complete all processes will be given a 60-minute waiting time to simulate waiting for the experimental results and then go back and line up in the waiting area.

Point 4: This part has two sections. The first one is that patients will be assigned to several departments according to probability, as shown in Table 12, which is based on hospital data.

Table 12. Percentage of visitors in each area

Destination	Percentage
MED (Room 2-6)	56%
EYE (Room 8)	14%
ENT (Room 10)	12%
OBG (Room 11-14)	13%
SKN (Room 15-16)	5%

When patients arrive in the queue of each department, they will be called into the room by the doctor. The room is divided into three parts. A is for the doctor to examine the patient, and the examination time (Table 11) will be provided by the distribution function of each doctor's ID who works that time. After the examination, the patient entity will be copied into patients and documents. The doctor will prepare documents in Area C, but the patient will leave the room first and go to the financial and pharmacy at point 6.

Point 5: At this point, the nurse aids go to the door of each examination room to pick up the documents filled out by the doctor and send them to the pharmacy. In addition to taking out files, employees are also given the ability to pick up files they pass by, simulating the reality that they will be asked to take documents from another room when they walk past.

Point 6: W-type patients will go directly to the pharmacy queue to wait, while others will wait in the financial queue. They are all waiting to be called by the front desk of each department (to pay money or get medicine). In the case of the document entity, the nurse aid will deliver it to the input buffer of the P1 server, which acts as the sticker printing staff.

After the data-filling process and sticker printing finish, the entity moves to the pharmacy room, where 2 to 3 workers will prepare the medicines. Then, they will pass the document to the pharmacist via availability. When finishing all the dispensing tasks, the entity of the document will move to destroy, while the patient entity will exit the system. If a patient must pay the money or sign the insurance paper, the document will be relocated to financial.

After the non-w type patient document arrives, the financial department will process the task of document checking and related paper preparation steps., before passing the document to the front desk, where the cashier staff call the owner entity of the document entity to perform a paying task. The functions of matching the document with the patient at this point are created by using the number assigned to the patient at the entrance, matching with the copy of the entity (document), which has the same number from point 4.

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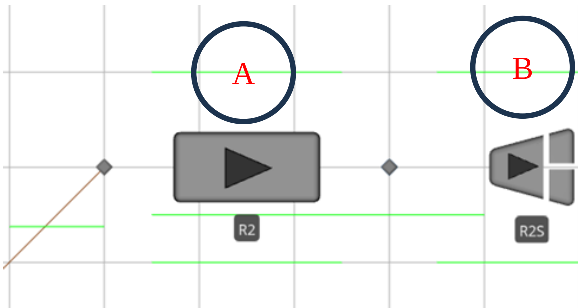

Room	Average leave time in Morning peak (minutes)	Average leave time in Morning peak (minutes)
2		38
3	67	69
4	65	
5	50	46
6		46
11	30	
12	52	
13		
14	40	

Fig. 10. Composition of one doctor room in SIMIO.

In addition, the doctor's working shift function, room changing function, and rest function are also implemented. The data on the working period are provided based on hospital record data, but it is the ideal working time of each doctor, where they will not leave for any issue during the shift. However, from the interview in Section 4 and the observation of the researcher, the situation where the doctor leaves the room frequently happens. Moreover, because the doctor is leaving, the number of queues in front of the doctor's room, financial, and pharmacy section will be affected.

To search for the effect of this activity, another set of data collection was conducted supported by nurse aid staff in each room. From 22/2/2023 to 24/3/2023, every time the doctor enters and leaves the room, the nurse aid will write down the time and reason for leave; the reason is in 4 categories.

1) ER: Going to the emergency room
2) Ward: Going to check the patient in the ward
3) Rest: Take a rest in a doctor's rest area or on personal leave
4) Other: Go to the operation room, perform the treatment outside the room, or go home

After the data are gathered, the leave time and the number of leave events that happen in peak time are in Table 13. The peak time of the OPD is between 8 and 11 am, with around 37% of visitors arriving, and 4 to 6 pm, the second-highest peak. The issues mentioned reveal that the model needs calibration to make the situation more realistic. Furthermore, if the doctor leaves the case, the new model can prove the severe level of the problem mentioned in Section 4: "The doctor is unavailable at an important time."

Therefore, the model will focus on simulating the doctor leaving issue. The leave time in each room will use the average leave time (Table 14). And calculate the chance

Table 14. Average leave time in each room.

of the doctor leaving at the same time each day.

The room with more than 20% leave cases will be chosen to calculate the average number to simulate the doctor's leave. Room number 10 also has a higher leave case than 20% in the afternoon. However, when talking to the staff, the doctor in this room always notifies the staff from the start of the day when the doctor has to perform the treatment or examination with some patient outside the room, the next slot will be closed, and the patient who comes after that will be informed. Next, calculate the chance of the doctor leaving that day and pick when the doctor leaves the room. For example, from the data, on Monday, 3 out of 4-week room 5 doctors leave the room in the morning, so there is a 75% (0.75) chance of the doctor leaving the room. Create the table in Excel, randomise the event, whether the leaving event occurs, and then assign the time the doctor leaves. Do this to every room, and a set of random leaving times for each room per day will be obtained in Excel (Table 15).

When patients get an appointment from the hospital, they will come at a different time than the paper has written. From the interview, many patients come the earliest they can reduce the waiting time. This situation will make the Vital Sign section different from the SIMIO model, where the patient arrives by the random number

Table 13. Leave event in peak period summary.

Room	Total	8 to 11 leave	%	MIN	MAX	16 to 18 leave	%	MIN	MAX	Absence
2	22	1	5%	20	20	16	73%	10	90	2
3	23	16	70%	15	120	16	70%	45	90	1
4	23	15	65%	45	95	1	4%	60	60	0
5	23	12	52%	15	70	5	22%	10	80	4
6	23	2	9%	15	30	5	22%	15	60	3
8	23	0	0%	0	0	1	4%	60	60	0
10	23	3	13%	15	35	5	22%	30	80	1
11	23	14	61%	15	60	1	4%	60	60	0
12	23	5	22%	15	180	0	0%	0	0	3
13	20	3	15%	40	115	1	5%	25	25	0
14	21	13	62%	10	120	4	19%	30	60	4
15	20	2	10%	10	50	3	15%	10	40	0
16	20	4	20%	5	20	0	0%	0	0	0

Table 15. Leave time set example.

	Monday	
	Morning leave start	Noon leave start
Room 2		16:00
Room 3	9:00	16:30
Room 4		
Room 5	9:00	
Room 6		
Room 11		
Room 12		
Room 13		
Room 14		
	Tuesday	
	Morning leave start	Noon leave start
Room 2		
Room 3		16:30
Room 4	8:30	
Room 5		
Room 6		
Room 11		
Room 12		
Room 13		
Room 14		
	Wednesday	
	Morning leave start	Noon leave start
Room 2		
Room 3	9:30	
Room 4		
Room 5	10:30	
Room 6		16:30
Room 11		
Room 12		
Room 13		
Room 14		
	Thursday	
	Morning leave start	Noon leave start
Room 2		16:30
Room 3	8:00	17:00
Room 4	9:00	
Room 5		16:30
Room 6		
Room 11	9:00	
Room 12		
Room 13		
Room 14	8:30	
	Friday	
Room 2		17:00
Room 3		16:00
Room 4	8:30	
Room 5	10:00	
Room 6		16:00
Room 11	10:00	
Room 12		
Room 13		
Room 14	8:30	

generator, and the data of the patient's arrival time cannot be observed through hospital data because the arrival time of the data in the system indicate the time where they registered into the system.

Another circumstance is that only some patients come to the hospital alone. In many cases, the patient comes in 2 or 3, sometimes a parent bringing their child, or the elderly who visit with a partner or family. Although this group did not go through the process, but will use the buffer with the patient

This section introduces the features and object functions of the SIMIO simulation software and realizes the contents of the OPD. Make the simulation more realistic with the doctor's random leave event and patient arrival. And point out the limitation that cannot simulate (early arrival). The content of this section will serve as the basis for optimising the simulation system in the following sections.

6. Analysis and Proposal discussion

6.1. Benchmarking

The research methodology mentioned that this research would summarise the literature and observe and understand how other hospitals are doing before improving current outpatient department performance. When selecting benchmarking hospitals, they need to have the following characteristics:

- There is a mixed patient health coverage type.
- Although the outpatient speciality differs, the observation hospital has relatively the exact space size.
- Similar peak periods of patient arrivals.
- Like the research hospital, the laboratory, finance, and pharmacy have separate departments, not a one-stop service OPD.
- Much of the process is similar. Some may have different internal steps, but the overall is almost the same.
- Experience with insufficient doctors or staff or a history of applying methods to reduce patient wait times.

Subject to the conditions mentioned above, contact the first-class or the best-reviewed hospital in the same or nearby city. Through email or telephone communication, the relevant departments that need to be visited and the framework of questions to be asked are proposed. Unfortunately, most of the best hospitals declined interviews or visits due to insufficient preparation time given to the hospitals or the content concerned with the privacy of the hospitals. Benchmarking can only switch from the best to the hospitals that do better than the research hospital or have a better ranking. Finally, got permission from four hospitals; in 2 of the hospitals, the researcher had a chance to conduct an interview session with the management level. At the same time, the other two data are gathered by observing and asking the floor staff only.

Creates the observing and interview questions by summarising the internal interview and observation of the current outpatient department (Table 16).

The first question focuses on how other hospitals do in their daily routines—creating the 4-sub question that affects the hospital outpatient department's current process. The second question is directly asked or observes how each hospital deals with the doctor's unavailable issue, the peak period of the day, and the delivery of documents issues. The third question expands from question two about how the patient knows their status. These two questions are related to the need for visual management usage in the current OPD environment. The last question created from one of the concerns points from the internal interview is how the staff checks each other's department status.

The observation was carried out on 10/5/2023 and 22/5/2023. Due to the hospital that gave the information

Table 16. Interview and observing questions for benchmarking.

Interview questions	
1	Related to current OPD steps
	Identifying patient rights
	Document work
	queuing
	Unique process or mechnism
2	Dealing with patient waiting issues
	The problem of insufficient doctors
	Delayed paperwork
	Checking where the documents are located
	Arranging shifts or managing people when there are a lot of patients during the day
3	Patient awareness
	How do they know what stage they are in?
	How do they know where to go next?
4	Internal document awareness
	What can they do to check the status of the document that the patient is in?
	How to check job status in different departments

wanting to remain anonymous, the name of each hospital will change into A, B, C, and D. After all the interviews, three main points can be adapted to the hospital's outpatient operational process.

Visual management plays an essential role in daily routines

Visual management makes problems or status visible and helps hospitals manage those situations, reacting as needed in the short term and solving the root causes of those problems in the long term.

From the observation, the hospital adapts visuals at various points for both customers and internally. In A hospital case, which is a private hospital, not only the doctor's name is shown on the screen, but also the status of whether the doctor left for what purpose (in some cases) is shown there. Both register staff and the patient can observe the location of the screen; hence, the nurse at the screening point and staff at the register can decide the doctor's arrangement according to the situation. When getting a question from the patient, all the staff can acknowledge and answer the situation instead of forwarding the question to someone else. In the system, the green, yellow, and red lights will indicate what step the patient is in, and they can also acknowledge all the steps from the slip (patient folder).

In B hospital, this private hospital creates the barcode on the queue code to scan the details of the patient, to let each counter be able to answer the question and guide the patient to the next area. Each zone is divided very clearly by colour to make the patients recognise the area they are in. Since C hospital is a government hospital, the design is heavily focused on easy to operate and control of the patient. The big screen is installed at the entrance to tell when each OPD operates (doctor schedule), which specialist queue is full or nearly complete, and when the register starts and closes.

Hospital D emphasises the importance of screening, and registered staff can acquire the details of the examination room situation and support screening in balancing the walk-in patients from screening. The staff also have a direction board to support the guidance, and on the screen of patient details, the green-red light in the system will show the situation in that section.

Dealing with staff and doctors insufficient

When mentioning doctors leaving the room, hospitals A, B, and D have different approaches to this situation. In comparison, A and B use the method of mentioning the patient about the doctor's status and trying to solve the problem proactively by talking with the patient for the patient, calling the doctor down, or telling them to change to the free doctor.

Hospital D focuses on a preventive approach where they try to set and control the leave time as much as possible. They create a policy for the doctor to finish the ward visit before starting to come to OPD, making it easier to balance the queue for appointments and walk-in patients. The leaving will be told to every related department, and the ER must have a separate doctor team so the doctor in OPD does not need to leave in an emergency. For the staff issue, a slide working schedule can also be used in Hospital D, while Hospital C trains the cross-function team to support the bottleneck area in the peak period. In hospital A, the doctor will always receive the updated patient list to calculate the time they need to spend and plan for adequate leave time during the day.

The document issues

All the hospitals in the observation acknowledge that reducing the use and delivery of documents will make their staff more available to service the customer. Starting from A hospital, they created a one-stop service OPD to make the document travel shorter distances. The staff will carry the document before the examination to avoid losing it. However, after examination, the patient will receive the VN slip and carry it to the financial and pharmacy. The staff still carried the long-distance documents. The method above reduced leave from the workstation of some staff by using visual support to guide the patient to the exact location and the traceable system (Green-red light) to race whether the document arrived at the destination.

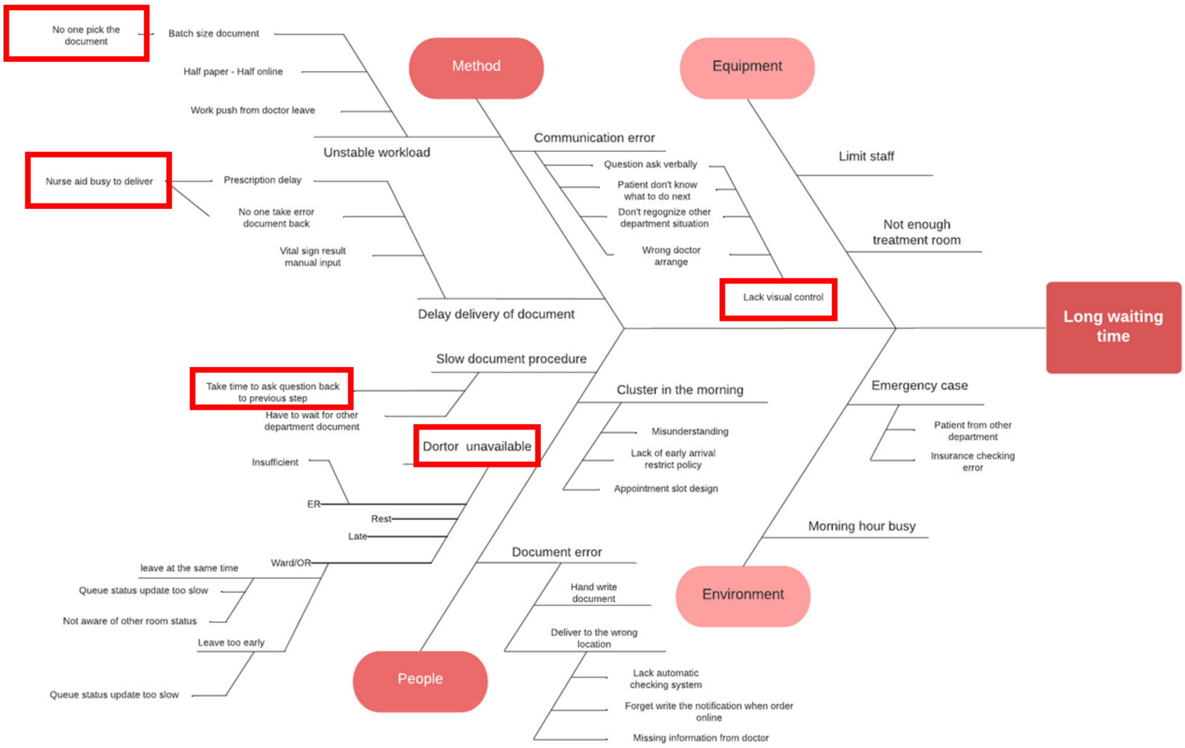

Fig. 11. Research fishbone diagram.

For B hospital. The only time the patient can contact the document is after they meet the doctor; they will have to deliver it to the staff, who sit at the table and wait for the document, such as the prescription and appointment details, to put in the basket in front of them. The staff will key the document detail and print a small queue paper with a bar code to check for information to the patients and ask them to go to the first floor at the financial and pharmacy department. The benefit of this process is making the patient acknowledge the paper already delivered from the room, and receiving the queue card means all the data is already keyed, and the staff at the following process receive the detail they need. The sense of participation makes the patient acknowledge that their data are in the hands of the following department now.

The time difference between the financial and pharmacy departments receiving the details is one of the issues that the staff mentioned in the interview. Hospitals A and D know that the faster they receive the detail, the faster they realise the error in the document. The policy of not writing prescriptions is used in both hospitals. While Hospital A still struggles with this policy, hospital D can make prescriptions 100% online with the help of support staff in the room, who are trained to support the doctor in keying the data. Moreover, since all data goes online, each section can check whether the staff responsible for each step finished the job. Furthermore, they will know the staff who key the data when an error or mistake occurs in the latter process.

6.2. Fishbone Diagram

A fishbone diagram or Cause and Effect diagram is one of the tools to help analyse the root cause of the problem. It is a structured process to help identify adverse events' underlying factors or causes. Understanding the factors contributing to Actions that cause system failures can help develop actions that support corrective action.

Using the data gathered from observation and interviews, the fishbone diagram of long waiting times in the outpatient department is created (Fig. 11). The diagram consists of two main points and two secondary problems. The two main problems are in the people and method category, where the current process and people's activity affect the waiting time of the outpatient department. The environment and equipment two indirectly affect the three problems stated before. From the interview and observation, many staff agree on the insufficient document delivery and nurse aid issue. Another main issue that causes the long waiting time, or longer throughput time in the system, is that the doctor is unavailable at a critical time, which links to the people category in the diagram. However, before giving the solution, the location of the bottleneck and the effect on the process must be located.

Before suggesting an approach to improve the system, each approach was discussed with the OPD chief. Apart from the improvement that each staff needs in the interview, the key point from the benchmark also summarised and presented the changing idea, which includes the change in working shift or doctor schedule, minor changes in the OPD layout, and installation or adding the device or system to several locations. After the concept approach was accepted, created a new simulation model by modifying it at various points to prove the modification benefit and introduced the useful Lean tool to improve the outpatient department's daily routines.

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6.3. Problem 1 Analysis and Approach

6.3.1. Effect of leave event

Create ten sets of leaving time for the doctor's room with the leaving event record and name it L1 to L10. Moreover, create ten sets of 1-week arrival table names A1 to A10. In SIMIO, create a new daily leave pattern with the average leave time for each room. Then, the data connector links the 10-arrival set that prepares for that leaving set model. One set of leaving time and arrival time is one scenario. Run the experiment 10 times per scenario. From the analysis, the leave event often occurs in MED and OBG rooms, so the first data that will be used to observe and compare is:

- The average waiting time in MED
- The average waiting time in OBG
- The average waiting time in FA (Financial)
- The average waiting time in PHA (Pharmacy)
- The average waiting time of documents in P1 (Sticker printing staff)
- The average time of W (Patient) entity in the system

Calculate each leaving set average time from the experiment report and compare it to the first model, where all the doctors work all the time without leaving longer than 30 minutes. The result of each observed data is shown in Table 17.

Table 17. Effect of leave event on SIMIO model.

	Without Leave	With Leave
MED - Average waiting time	506	696
OBG - Average waiting time	176	179
FA - Average waiting time	922	902
PHA - Average waiting time	622	605
P1 - Average waiting time	211	185
W - Average waiting time	1949	1999

The next step is to check the situation at the financial and pharmacy departments, whether they receive the effect, and how severe the effect is. The financial and pharmacy waiting zones have remarkable results, where the average waiting time decreases while the maximum waiting time increases. The reason is that the leave event makes the MED patients come to this department slower, giving them a better flow during the day. However, in contrast, it makes all the work cluster or bunch in the same period, resulting in higher waiting times for some customer groups. This is against the aim of heijunka or levelling, where hospitals should avoid patients gathering simultaneously at one location, leading to reduced workload and fatigue. An imbalance of work means being unable to control delivery, leading to waiting and wasted.

To check the significance level for the change, run the Student's t-test in Matlab to check the p-value of each leave set to the original model (Table 18), with a confidence level of 95%, and alternative hypothesis H_1: $\mu_1 - \mu_2 > 0$, or H_1: $\mu_1 - \mu_2 < 0$.

Table 18. P-value of each variable (Leave event experiment).

Comparison item	Alternative hypothesis	p-value (t-test)
The average waiting time in MED	H_1: $\mu_1 - \mu_2 > 0$	0.000
The average waiting time in OBG	H_1: $\mu_1 - \mu_2 > 0$	0.272
The average waiting time in FA	H_1: $\mu_1 - \mu_2 < 0$	0.175
The average waiting time in PHA	H_1: $\mu_1 - \mu_2 < 0$	0.119
The average waiting time of documents in P1	H_1: $\mu_1 - \mu_2 < 0$	0.008
The average time of W entity in the system	H_1: $\mu_1 - \mu_2 > 0$	0.011

Note: μ_1: L0 average value, μ_2: L1-L10 average value.

The first set of L1 to L10 leave time significantly affects the average MED waiting queue and the average waiting time in the system entity. The next step is to re-arrange the leave period and check whether the waiting time has been reduced.

6.3.2. Leave time proposal

Set 1

From the doctor leaving data gathered, most of the time, only 4 to 3 rooms are often open simultaneously in the MED section. Furthermore, there is a time when only two doctors are working in this peak period, which means only 40% of the workforce is working. For the reason of leaving, most of the leave is going to the ward, and the second is to rest. The leave percentage of each room in the peak period compared to total leave is shown in Table 19.

Table 19. MED doctor peak period leave percentage.

Room	Total Leave	Peak period leave	Percentage
2	60	17	28%
3	68	32	47%
4	42	16	38%
5	48	17	35%
6	17	4	24%

Therefore, the solution would revolve around designing the schedule to reduce the chance that the doctor's room opens lower than half and try to find adequate time to leave.

The first proposal aims to implement an overlap-breaks schedule to guarantee the maximum output of the doctor's room in each period. Before creating the new leave time set, each day's average leave slot must be calculated. Calculate the average leaving hour of each day's peak period using the doctor's leaving data, as shown in Table 20. Next, distribute these leaving times to the room with the leave event record.

Table 20. Daily total Avrage leave hour of MED.

	Average morning leave	Average noon leave
Monday	3 hours	1 hour
Tuesday	1.5 hours	0.5 hours
Wednesday	1 hour	0 hours
Thursday	2.5 hours	2.5 hours
Friday	2 hours	2 hours

The orange box in Fig. 12 shows the doctor leaving the room, while the black box is when no doctor works from the schedule. With the new leaving table (L11), create the SIMIO model and set the doctor's leaving time as the same as the figure. The only day that cannot fit the slot is Thursday, where only two rooms, 3 and 4, have leave events. One of the slots has to move outside the peak period. Running the new experiment with the same arrival rate A1 to A10 to check the before and after the change with the same quantity of patients and arrival time. The result of the L11 experiment is shown in Table 21.

Table 21. L1 to L10 average and L11 result comparison.

	L1 to L10	L11
MED - Average waiting time	696	645
MED - Average maximum waiting time	4033	3892
FA - Average waiting time	902	956
PHA - Average waiting time	605	647

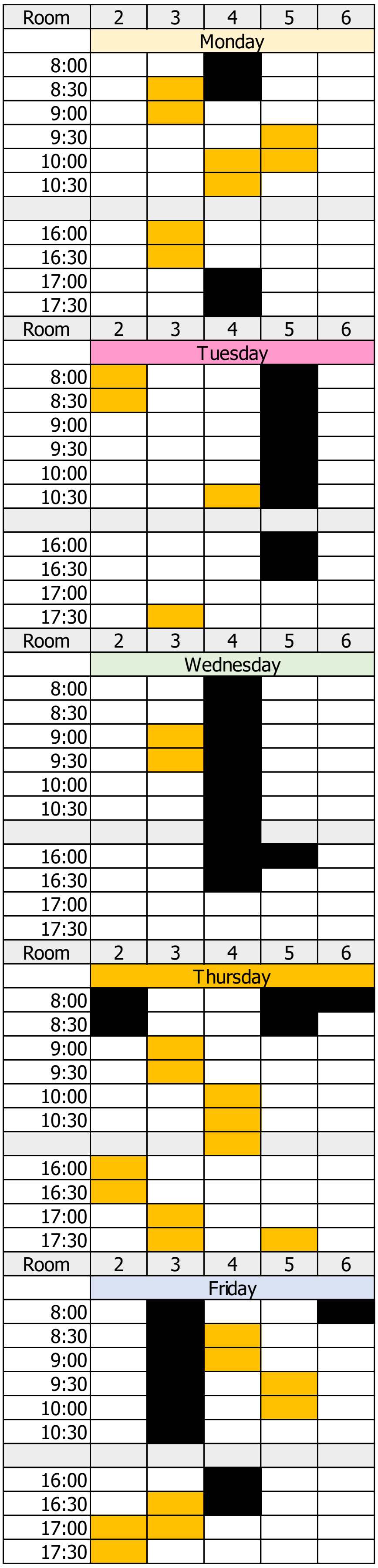

Fig. 12. Set 1 leave time slot.

By balancing the MED leaving queue with the overlap break method, there is a significant decrease in the waiting time from an unorganised leave event. In contrast, the waiting time in both the financial and pharmacy departments increased, leading to an insignificant change in the waiting time of W Entity, as shown in Table 22.

Table 22. P - value of each variable (Set 1 result).

Comparison item	Alternative hypothesis	p-value (t-test)
The average waiting time in MED	$H_1: \mu_1 - \mu_2 > 0$	**0.039**
The average waiting time in FA	$H_1: \mu_1 - \mu_2 < 0$	**0.005**
The average waiting time in PHA	$H_1: \mu_1 - \mu_2 < 0$	**0.011**
The average waiting time of documents in P1	$H_1: \mu_1 - \mu_2 < 0$	**0.008**
The average time of W entity in the system	$H_1: \mu_1 - \mu_2 < 0$	0.058

Note: μ_1: L1-L10 average value, μ_2: L11 average value

Set 2

The second method design extended from the first set, combined with Hospital D's policy of letting the doctor finish the ward before coming to the room. Nevertheless, for this outpatient department, the later the doctor left, the better. Move all the leave slots to happen after 10 in the morning and 17 in the afternoon. The idea focuses on having as many doctors as possible in the morning, allowing them to leave after a specific time. Because appointments are from 7 to 10 am, and both appointments, walk-ins, and appointments arrive early, patients will come in simultaneously. From the hospital record, this group stands at 35% of daily visits; the lack of doctors during this period will affect the whole process. The new leave time set, L12, is shown in Fig. 13, using the same average leave hour as L11. Create the new daily pattern of doctors in SIMIO and run the experiment of each arrival time.

From the results in Tables 23 and 24, the p-value of each item is smaller than 0.05, which shows the second set of leave schedule, where the leaving period away from morning patient group visit has a significant effect on reducing the waiting time, proving the assumption that leaving an event in the busy hour make the overall waiting time increase is correct.

When looking into why each room was left in the peak period in Table 25, visiting the ward accounted for more than 60%. So, without increasing the workforce, the best option is to avoid leaving between 8 to 10 am. After a specific period, the number of doctors' rooms can be reduced by reducing the daily visit rate.

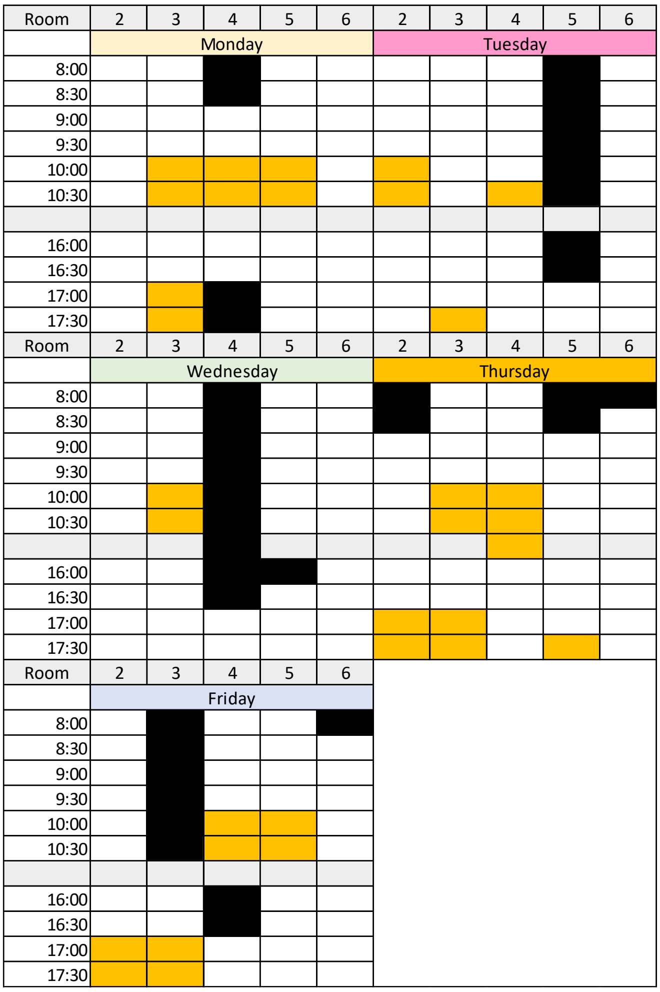

Fig. 13. Set 2 leave time slot.

Table 23. L1 to L10 and L12 result comparison.

	L1 - L10 average	L12	Percentage
MED - Average waiting time	696	605	-13%
MED - Average maximum waiting time	4033	3790	-6%
FA - Average waiting time	902	850	-6%
PHA - Average waiting time	605	572	-5%

Table 24. P - value of each variable (Set 2 result).

Comparison item	Alternative hypothesis	p-value (t-test)
The average waiting time in MED	$H_1: \mu_1 - \mu_2 > 0$	**0.035**
The average waiting time in FA	$H_1: \mu_1 - \mu_2 > 0$	**0.005**
The average waiting time in PHA	$H_1: \mu_1 - \mu_2 > 0$	**0.020**
The average waiting time of documents in P1	$H_1: \mu_1 - \mu_2 > 0$	**0.012**
The average time of W entity in the system	$H_1: \mu_1 - \mu_2 > 0$	**0.005**

Note: μ_1: L1-L10 average value, μ_2: L12 average value .

Table 25. Each room leaves reason and time.

2	M	N	11	M	N
R		5	R		
W	1	7	W	12	
O		3	O	2	1
ER		1	ER		
3			12	M	N
R		13	R	2	
W	14	3	W	2	
O			O	1	
ER	2		ER		
4			13		
R			R		
W	15	1	W	1	
O			O	2	1
ER			ER		
5			14		
R			R		4
W	9	4	W	11	
O			O	2	
ER	3	1	ER		
6					
R		3			
W	1	2			
O					
ER	1				

However, creating a policy for every outpatient department that doctors cannot leave in any case is hard to adapt because D hospitals can use the policy because they have more doctors and room to support the leave event in the early morning, and several doctors work schedule end before noon; shifting the leave event after the peak period as much as possible will lead to the doctor cannot leave the hospital to other places or cannot finish all the ward rounds.

6.3.3. Remark from proposal

The L12 method helps reduce the overall waiting time, but, in the capacity issue, when comparing the random leaving event, L11, and L12 status plot results, there are only several scenarios that the number of patients exceeds the number of seats but when considering the 30% of patient have someone who comes together and require using the chair, there is the range during morning period where the visitor of buffer 1 exceed the chair number as shown in Fig. 14.

The overcapacity situation happens when the leave event occurs and results in the pushing waiting to see the doctor-patient to the latter process simultaneously. The chair-exceeding event can be seen in L1 to L10 and L12, where the number of doctors leaving the event happens in the same time slot.

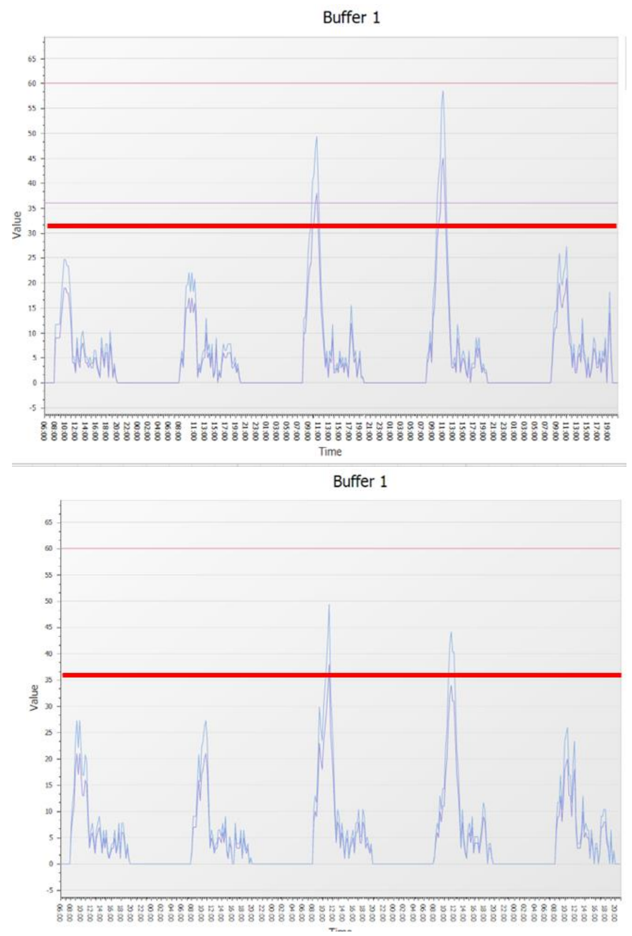

Fig. 14. L1-L10 and L12 buffer 1 status plot.

In contrast, the number of queues if the overlap-break schedule(L11) is lower than other leave time sets, as shown in Fig. 15. The flow of people is more evenly distributed.

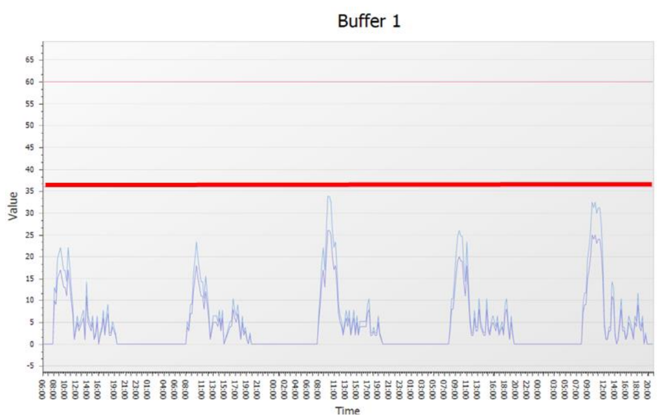

Fig. 15. L11 buffer 1 status plot.

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From all the experiment results, the internal cause of bottleneck belongs to doctor leave events that cause the increment of waiting time of each patient in that period and the working load of the after-examination department. However, the other reason is that the patient group arrives early in the morning. In contrast, more than the ability of the outpatient department to serve this amount of patients is needed. Changing the leave schedule alone will only shift the waiting capacity from one location to another.

Furthermore, currently, between 8 and 9 am on weekdays, the hospital can only open some of the doctor's rooms to serve the current number of visits without causing another issue in another department. Besides an internal preventive plan to increase schedule flexibility, the hospital must also consider balancing the visit rate.

6.3.4. Other proposal

Set the queue card-giving policy.

This solution is valid with hospital C, where the hospital policy will not give the queue card to patients who arrive two hours early. The time can change according to each hospital size; in hospital C, the visit rate of one OPD specialist can be more than the daily visit rate of the research hospital OPD.

The hospital aims to increase the number of daily patients they can serve and focus on having more non-W patients. However, since the W-type patients are the biggest group, it is essential to distribute this patient group more during the day. By setting the policy of appointment W type, patients will not be given the queue if they come 1 hour earlier.

Provide the basic information of the queue with visual monitoring.

According to the current process of the OPD, the nurse at the scanning point will hold the paper of the doctor who is working today and distribute it to the patient who did not need to meet any doctor by themselves, with the information provided by the nurse aid around the OPD. The floor plan in Fig. 6 shows the nurse's area at the screening point and the location of each queue screen (dot). The screen and each room situation cannot be fully observed; hence, the situation is not real-time, and there will be a chance that the walk-in patient will be sent to a longer queue. The suggestion is to improve the queuing quality by adding a status screen showing the number of queues for each doctor and doctor situation to the nurse at the screening section.

The screen in Fig. 16 will support information sharing for both staff at screening and patients. The staff can show the patients the data of the doctor they wish to meet to make them understand the overall situation of each doctor's room, the approximate time they need to spend in the hospital, and how many queues there are before them. Furthermore, without asking anyone, the nurse can know the doctor's situation, like leaving, working, or late arrival, by glancing at the colour dot.

The screen's location can be installed at the wall behind the area, covering the sight of the Wecare staff guiding non-W patients and those who queue at the screening area (Fig. 17). This method can help level the queue and act as a signal if the number of patients in the system exceeds the capacity of the outpatient department. Support the decision to ask the patients to come back an hour later because there is no waiting space or prepare to ask we care to ask for cooperation for patients to change the appointment time that day. Changing the method from pushing a patient to the next step instead of letting the doctor signal the former step whether they are ready to work or not.

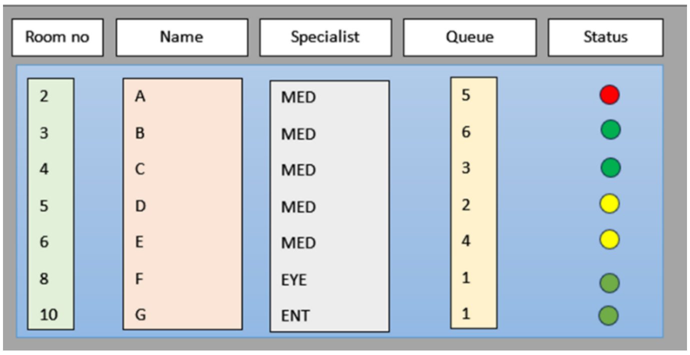

Fig. 16. Example of doctor status screen.

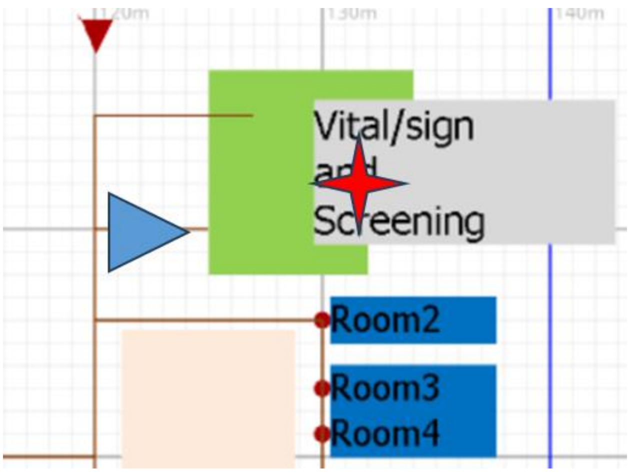

Fig. 17. Screen location at screening table.

Visual control proposal - Andon

In the fishbone diagram, doctors leave because they are unaware of another doctor's status or the information they know is not updated. Another side of the diagram also mentions communication issues. In one room, the doctor and nurse aid are working to support the doctor in that room all day. The nurse aid will be the one who asks to screen other room staff or the patient about the current OPD situation. This method requires several verbal communication steps or checking other document details, which requires time and sometimes can cause errors.

Fig. 18. The time when other staff acknowledge the doctor will leave the room.

Hence, visual control is an effective tool to communicate to all employees about important information in the workplace.

Visual control is a work control system that allows all employees to quickly understand work procedures, goals, and work results, as well as to see any abnormalities and fix them quickly using boards, signs, symbols, graphs, and colours. Figure 18 shows the current time stamp where the staff outside the doctor's room acknowledge the doctor's status.

Most of the time, the doctor will tell the nurse aid when they are going to leave, but the conversation is in the room where the only person who knows is the nurse aid. However, nurse aid also has to support the doctor in record or treatment in the room, so the time that other staff, such as screening, front service, and the wecare, will acknowledge only when the doctor leaves the room, which gives another team too short for any adjust, such as other doctors will also leave the room soon, or screening already pick that doctor for the walk-in patient.

Furthermore, the leave event can be seen only by staff in sight; the financial or pharmacy will not know the event is happening, which leads to the question being passed to the nurse's aid when a document error happens. If the doctor is not in the room, the nurse aid has to call or find the doctor to ask the question, wasting time instead of creating value. If the doctor's assistant is unavailable at that time, these two departments have to solve the problem by themselves, leading to a shortage of employees.

In the short term, each doctor's room can have a small transparent plastic case near the door, and when the doctor is present, ready to leave, or absent, choose different coloured paper to put in it. However, Lean recommended that information displayed within visual management systems be easily readable from a distance of around 1.5 to 3 meters.

The nurse aid who walks around is the only staff member who acknowledges it by putting it at the door. Hence, it does not help the screening nurses or front service, and it is complex to collect information for optimisation. From the floor plan, the examination rooms are spread out in various corners around the OPD. Short, easy-to-understand communication will make the whole process more effective and efficient. The hospital can design the three-colour button to indicate the doctor's situation (Fig. 19).

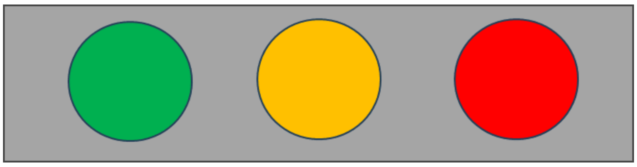

Fig. 19. Doctor status button.

The panel is set in the examination room, where nurse aid can quickly push to turn the light on at another team screen. Red is the doctor leaving the room, green is working, and when all the lights are off, the doctor has already gone home or has not arrived yet. This method requires the installation of wires and panels, which requires more investment, staff cooperation, and practical experiments than short-term methods.

Considering the overall beauty and tidiness of the outpatient and the privacy of information, the display screen can face the employees at each counter, such as the front service and pharmacy. The advantages of Andon are:

- Notify in advance

The difference between turning off the light or flipping the hanging cardboard, using the traffic light principle by having yellow colour as the notice related to the department that the doctor will leave the room after the current patient or in 15 minutes will benefit in giving other staff the time to discuss or adjust their plan.

As Fig. 20 shows, without nurse aid passing the leave notice, all the related counters will receive the signal at the same time, and these data will be saved on the computer system, used in optimisation or helping management level to increase the human resources. The chance of a doctor leaving at the same time is directly reduced. Although there is no information about other rooms in the examination room, the same specialist doctor will receive these notifications since nurse aids would have come out to deliver documents or consult other departments. Front service can also answer if the patient comes to ask them since their area is the largest and in the centre.

Fig. 20. The time when other staff acknowledge the doctor will leave the room with Andon.

- Eliminate unnecessary process

In this section case, using ECRS to eliminate, combine, rearrange, or simplify the process which affects the doctor leaving the event A shown in Fig. 21 when a Pharmacy or financial has an issue with the document that requires contacting the doctor's room, they do not know whether the doctor can answer them. The question has to pass through the nurse aid that passes by since they are in enclosed spaces, and some processes only have one counter.

The nurse aid who responds to the doctor sometimes leaves the room when the doctor is away, so it takes time to ask or find the answer. The document of that patient will be forced to "wait" or "stop" the situation.

1) Eliminate: Andon will support eliminating unnecessary movement, both documents and people. In the red circle, the step of passing the question will be eliminated, along with moving the document in some cases.
2) Rearrange: Change the checking logic; instead of checking where the assistant nurse aid or anyone is to support them; instead, they check the doctor's status from the screen first (Black circles).
3) Simplify: Simplify the searching for answer task by creating more areas that can check the doctor's location and details, making the staff ask for screening or staff in that area because they already received the notice.

The new process, with the support of colour-coded signs and labels, is shown in Fig. 22.

Fig. 21. Current process when prescription have the issues.

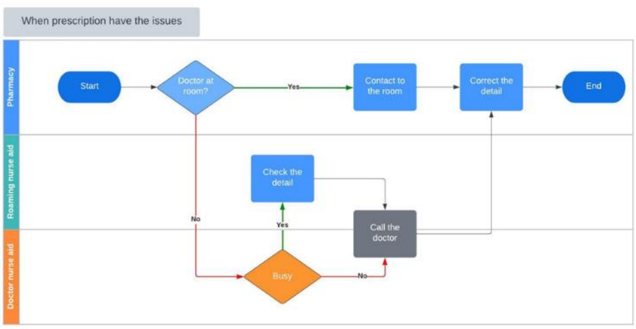

Fig. 22. The new working process when prescriptions have the issues after the optimization.

6.4. Problem 2 Analysis and Approach

6.4.1. Delivering document analysis

On the one hand, patients do not need to touch any internal documents, which is what the service industry should do. However, the premise is that the person responsible for transporting documents can achieve low latency in sending documents. According to the customer's perception, his files will arrive at the next working point in the fastest time, but during the observation cycle and interviews, it is evident that workers cannot do this. The reason is that even though it is not in the peak period, there will occasionally be a person with many files, which will cause some work rate instability at the P1 work point. They do not know how long the file has been stored, and customers will complain to them for slow work despite the document arriving just a while ago.

Furthermore, there is no standard for the delivery routes; they only move to pick when they see and take others when passing by, and they have to deliver the document to two locations: the appointment desk and the

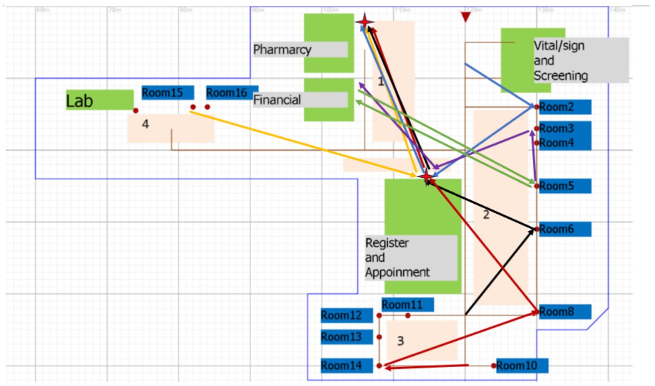

Fig. 23. Nurse aid movement record.

pharmacy department. Figure 23 is the trajectory from observation of one nurse aid delivering documents.

To check and prove the need for nurse aid in the delivery process, modify the SIMIO model by adjusting the NA (nurse aid) number. The experiment will run with two nurse aid and three nurse aid, using the exact arrival time set A1 to A10, run each scenario ten times using the L11 model leave time, which applies an overlap-breaks schedule; the timing of this experiment is to observe the distance that each transporter travel, the idle percentage, and working percentage. An additional experiment compares the change in waiting time of specific locations and overall waiting time in the system.

6.4.2. Result analysis

The data that will be observed and compared from the report is

- The average distance travels
- The average Idle percentage
- The average transporting percentage
- The average waiting time in FA
- The average waiting time in PHA
- The average waiting time of documents in P1
- The average time of W entity in the system

Table 26 shows the average distance of a worker from the doctor's room to the P1 location in a 120-hour simulation. The work schedule is designed to let nurse aid start working from 7 am until 9 pm, 14 hours in total. In the first model, a nurse aid spends around 475.2 minutes transporting the patient document, with a travel distance of 21,606 meters per day. When two nurse aids work together, the average time spent delivering the document is 259 minutes per person, with 12,935 meters of travelling distance. When three nurses are responsible for delivering documents in one day, the average time and distance they walk are 172 minutes and 8799 meters.

Table 26. L11 model with 1,2, and 3 nurse aid result comparison (1).

	1 (L11 - 1NA)	2 (L11 - 2NA)	3 (L11 - 3NA)
The average distance travels	108031	64675	43999
The average Idle percentage	25.71	40.47	45.96
The average transporting percentage	32.62	17.87	12.38

Table 27. L11 model with 1,2, and 3 nurse aid result comparison (2).

	1 (L11 - 1NA)	2 (L11 - 2NA)	3 (L11 - 3NA)
The average waiting time in FA	956	852	847
The average waiting time in PHA	647	570	567
The average waiting time in P1	206	274	278
The average time of W entity in the system	2032	1947	1941

After looking at the nurse aid workload from using them to deliver the document, the next step is to analyse whether increasing nurse aid can solve the waiting time problem. First, compare the model with one nurse aid to 2 in Table. There is a significant decrease of 11 to 12% in the average waiting time of entities in the financial and pharmacy queue. However, in Table 29, adding one more nurse aid to the system did not make any significant changes to the system anymore.

Table 28. P - value of each variable (L11 model with 1 and 2 nurse aid)

Comparison item	Alternative hypothesis	p-value (t-test)
The average waiting time in FA	H_1: $\mu_1 - \mu_2 > 0$	**0.000**
The average waiting time in PHA	H_1: $\mu_1 - \mu_2 > 0$	**0.000**
The average waiting time of documents in P1	H_1: $\mu_1 - \mu_2 > 0$	1.000
The average time of W entity in the system	H_1: $\mu_1 - \mu_2 > 0$	**0.002**

Note: μ_1: L11-1NA average value, μ_2: L11-2NA average value.

Table 29. P - value of each variable (L11 model with 2 and 3 nurse aid).

Comparison item	Alternative hypothesis	p-value (t-test)
The average waiting time in FA	H_1: $\mu_1 - \mu_2 > 0$	0.420
The average waiting time in PHA	H_1: $\mu_1 - \mu_2 > 0$	0.444
The average waiting time of documents in P1	H_1: $\mu_1 - \mu_2 > 0$	0.585
The average time of W entity in the system	H_1: $\mu_1 - \mu_2 > 0$	0.422

Note: μ_1: L11-2NA average value, μ_2: L11-3NA average value

Moreover, in this simulation, all nurse aids are;

- Standby waits for the patient's document to be put in front of the examination room, and they will move to that location with the fastest speed and closest direction. In reality, referring to the observation time is necessary, and employees might start at different locations.
- The idle time in the table means that the nurse aid may be busy with another daily task in service to the patient and cannot participate in picking up the documents, especially during the morning

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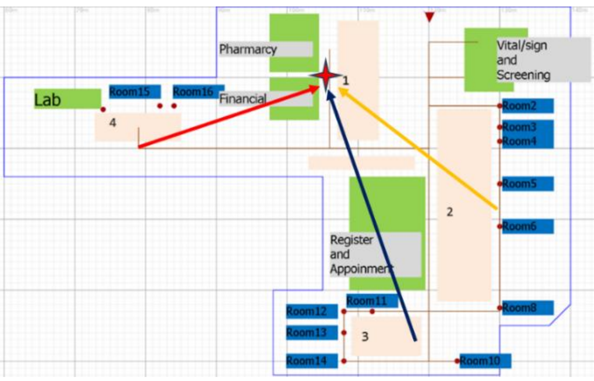
peak period. In this case, a batch of documents will be picked up and sent to the pharmacy again.

- In this experiment, only the document coming from the examination room was simulated. It did not consider that if there were a problem with the file, the staff team would also be busy solving the problem.

Therefore, using these employees in other places, such as positions that can create value or reduce waiting time, will be a better choice.

6.4.3. Remove delivering documents step

This experiment aims to try to let nurse aid stop being responsible for transporting the documents after the examination. After the examination, the patient needs to wait in front of the room. After a period of time, the nurse aid will give them the documents, such as appointment details and medicine letters and will guide the patient to the destination. The nurse aid must move through 2 locations to put down the document. First is the appointment table in front service, and second is the P1 table location. The new design in Fig. 24 aims to reduce complex instructions for patients, so assume that there is a small counter between the financial and pharmacy space that can sort the documents that the patient drops and will transfer the different patient-type documents in the right direction.



Start from changing the doctor room object in SIMIO;

Fig. 24. The patient path to put down the document from various locations

when the entity exits the examination server, instead of entering the separator and moving to the next station, it will have to enter another server simulate waiting for the doctor to fill out the document or input the data into the computer in front of or in the room. Then, the patient will move to the next location with the same logic, and the document entity will be copied at the counter in the financial and pharmacy section instead.

6.4.4. Results summary and new findings

Remove the requirement of transporter after examination in output buffer properties, and run the experiment using the exact arrival time set A1 to A10 in each scenario ten times, using the L11 model. The data that will be observed and compared from the report is

1) The average waiting time in FA
2) The average waiting time in PHA
3) The average waiting time of documents in P1
4) The average time of the W entity in the system

Use the L11 leave set model with 1 to 3 nurse aids compared with the new experiment report from the L11noNA model.

Table 30. L11 model with 1,2,3 nurse aid, and no nurse aid result comparison.

	1 (L11 - 1NA)	2 (L11 - 2NA)	3 (L11 - 3NA)	4 (L11noNA)
1)	956	852	847	763
2)	647	570	567	504
3)	206	274	278	284
4)	2032	1947	1941	1897

Table 31. P - value of each variable (L11 model 3 nurse aid with no nurse aid).

Comparison item	Alternative hypothesis	p-value (t-test)
The average waiting time in FA	$H_1: \mu_1 - \mu_2 > 0$	**0.003**
The average waiting time in PHA	$H_1: \mu_1 - \mu_2 > 0$	**0.003**
The average waiting time of documents in P1	$H_1: \mu_1 - \mu_2 > 0$	0.616
The average time of W entity in the system	$H_1: \mu_1 - \mu_2 > 0$	0.071

Note: μ_1: L11-3NA average value, μ_2: L11-noNA average value

The results in Tables 30 and 31 show that financial and pharmacy queue waiting times significantly decreased. While the average time in the system is decreasing, the P value is still higher than 0.05%. For a roughly 11% reduction in financial and pharmacy wait times, demonstrating the benefits of not having designated staff to transport these documents. The advantages outweigh the disadvantages in

- Reduce the moving distance of the related employees. As mentioned in 6.4.3, if three employees are removed from this task, they will each reduce the moving distance by more than 8,000 meters daily. Moreover, the 172 minutes taken out can be used to produce value for customers.
- The moving distance of each patient is the same; if the instructions are appropriate and the location of the document basket is obvious, they will not get lost easily.
- The freed-up time allows them to assist with urgent matters, such as a lack of people in the morning for

blood pressure measurement and serving guests who need assistance (wheelchairs or higher ESI levels).

- During the customer journey, customers care about whether the waiting time is too long, and sometimes they do not know their status due to the delay in the delivery of documents. They will have a certain sense of participation in the new process and feel at ease when they put down the documents. Now, they can confirm that their medicine or payment documents are in preparation.

From the above experiment in this section, It can be observed that regardless of changing the number of nurse aid or removing them from participating in the transfer of files, the workload of P1 did not affect reduction but had some insignificant increase. This implies that a workbench cannot handle the current workload during peak periods; the experiment of P1 staff adjustment is needed to inspect these matters.

6.4.4. Increase sticker printing staff

Changing the capacity of P1 at one from 7:00 to 9:00 pm to 2 staff from opening until 11:00, adding the new process trigger when the entity enters the P1 server, the decide step will read the current time of this system. The period selection refers to the status plot in the simulation experiment, as shown in Fig. 25.

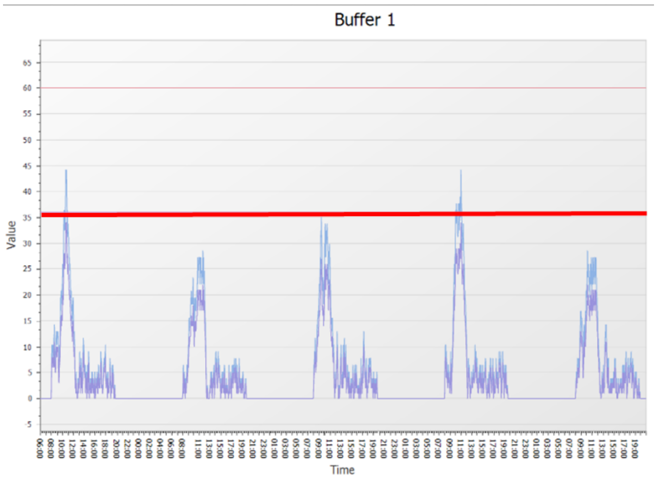


Fig. 25. The status plot of the experiment shows the congested period.

This adjustment will be simulated in two experiments: the first in the experiment where the nurse aid has been removed, the second in the original model with three NAs, and the last model is the L12 set model where the leave event will happen only after 10 am., to check the efficiency of the experiment for each design.

The result in Tables 32, 33, and 34 shows that having nurse aid deliver the document case resulted in a decrease in four observing data, proving that increasing human resources at the location during the morning peak hour reduces the overall wait time of patients after the examination.

In the no-Na case, the waiting time for each item also decreased, as shown in Tables 35 and 36. In particular, the waiting time for prescriptions in P1 has been greatly reduced. In addition to batch file sending, the number of personnel at that time also affects the flow of subsequent work.

If calculated by the average working time of P1, which is 65 seconds, the sticker printing desk can serve about 55 files in one hour. The average arrival per day is 408; when divided by the arrival percentage per hour, from 7 to 10, the arrival number in each hour slot is 36, 51, 57, and 41. Although the number does not exceed the capacity most of the time, the following situations need to be considered in reality:

- When some doctors need patients to receive treatment outside the examination room, nurse aid will bring the document to the exact location to print stickers.
- When there is some error in entering the required quantity and writing on paper, the staff at this location should also stop working and contact nurse aid to consult a doctor.
- These documents do not come one at a time because the patients who come will come out at different times under the examination of other doctors, resulting in sometimes, even though the documents do not come in batches, they are continuously stacking in front of P1.

Table 33. P - value of each variable (L11 1 P1, and 2 P1).

Comparison item	Alternative hypothesis	p-value (t-test)
The average waiting time in FA	$H_1: \mu_1 - \mu_2 > 0$	**0.001**
The average waiting time in PHA	$H_1: \mu_1 - \mu_2 > 0$	**0.001**
The average waiting time of documents in P1	$H_1: \mu_1 - \mu_2 > 0$	**0.000**
The average time of W entity in the system	$H_1: \mu_1 - \mu_2 > 0$	**0.008**

Note: μ_1: L11-1P1 average value, μ_2: L11-2P1 average value.

Table 32. 1 and 2 P1 result comparison.

	L11 before	L11 after	%	L12 before	L12 after	%
The average waiting time in FA	847	766	-9%	850	802	-6%
The average waiting time in PHA	567	508	-10%	572	532	-6%
The average waiting time in P1	278	58	-79%	157	48	-70%
The average time of W entity in the system	1941	1867	-3%	1935	1882	-2%

Table 34. P - value of each variable (L12 1 P1 and 2 P1).

Comparison item	Alternative hypothesis	p-value
The average waiting time in FA	$H_1: \mu_1 - \mu_2 > 0$	**0.019**
The average waiting time in PHA	$H_1: \mu_1 - \mu_2 > 0$	**0.015**
The average waiting time of documents in P1	$H_1: \mu_1 - \mu_2 > 0$	**0.000**
The average time of W entity in the system	$H_1: \mu_1 - \mu_2 > 0$	**0.031**

Note: μ_1: L12-1P1 average value, μ_2: L12-2P1 average value

Table 35. L11noNA with 1P1 and L11noNA with 2P1 model result comparison.

	L11 (NoNa) before	L11 (NoNa) After	%
The average waiting time in FA	763	672	-11%
The average waiting time in PHA	504	439	-12%
The average waiting time in P1	284	57	-80%
The average time of W entity in the system	1897	1820	-4%

Table 36. P - value of each variable (L11noNA with 1P1 and 2P1).

Comparison item	Alternative hypothesis	p-value
The average waiting time in FA	$H_1: \mu_1 - \mu_2 > 0$	**0.001**
The average waiting time in PHA	$H_1: \mu_1 - \mu_2 > 0$	**0.001**
The average waiting time of documents in P1	$H_1: \mu_1 - \mu_2 > 0$	**0.000**
The average time of W entity in the system	$H_1: \mu_1 - \mu_2 > 0$	**0.008**

Note: μ_1: L11-noNA 1P1 average value, μ_2: L11-noNA 2P1 average value.

The result of this section proves that the increment of the workforce for 4 hours in the morning helps increase the flow of documents and patients after the examination. The average amount can be smaller when combined with the leave schedule, which levels the patient flow from the examination room to the financial and pharmacy.

6.4.5. Layout changing proposal

From the experimental results in this section, if it is necessary to remove the process staff transport documents, there needs to be a team next to the financial and pharmacy that can help check the documents detail placed by the patient, hand them to the relative position, be able to prepare the appointments paper, and team checking doctor's status. This team can benefit the overall outpatient process in the following ways;

- Previously, finance, pharmacy, and the before-examination process were separated into three teams, working and communicating with each other. However, when a problem arises, the consultation or Q&A of each team still needs to be passed through the message. When the finance and pharmacy are busy, most of the workload is in the hands of nurse aid. If a team can immediately investigate the root cause of the problem and adjust the workflow, it will reduce the time each team needs to spend. When financial and pharmacy requests are received, they can provide information, such as where the doctor leaves, when they need to confirm the medicine dose, to check the appointment date and medicine dose match, or the customer's medical insurance information.
- This team is not just a question-answering department; they are still connected with the front desk and nurse aid. They are responsible for preparing the appointment letter, and because of the spare time obtained by cancelling the document-delivering process, the staff can focus more on serving the patient.
- The finance staff needs to wait passively until the documents from the pharmacy arrive when the pharmacist finishes the preparation process before they can start working. This method will add a small workbench with a screen to notice how many people are in the hands of the pharmacy department, which is non-w type, so they can prepare relevant documents faster.

There are two proposals for layout in this chapter.

Set 1

The first set in Fig. 26 moves the appointment table from the front service area (red star) to the window next to the financial.

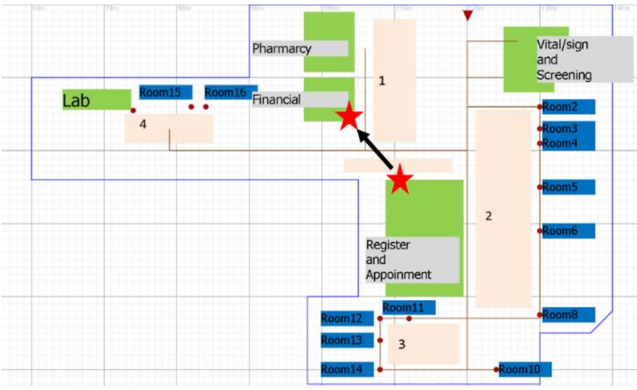


Fig. 26. Set 1 layout.

Because this is the location where most of the patients must pass when they need the appointment card, pay the fee, or receive the medicines. Furthermore, it is still in the corner where the patient walks from the lab; rooms 15 and 16 can also see the sign. This team can replace the financial and pharmacy to check the data in the related data, the doctor's situation, and the error of the document. With the location advantage, the hospital can install a small light signal or flip the cardboard with a letter according to the situation to make nurse aid easier to notice and receive the task. Figure 27 below shows the new counterwork environment from above.

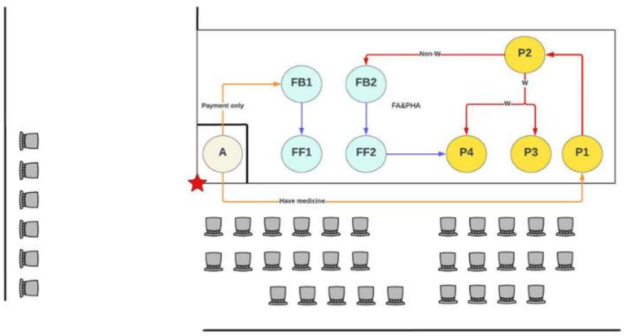


Fig. 27. Set 1 working environment.

Currently, there are three service windows in the financial department, but only two of them are used, so the idea of using that space is to create the paper delivery and pick a spot for the outpatient team. The red star in the figure can be the location where the small light bulb is installed or the colour sign notifying the location for the patient to put down the document. The internal area will consist of a working table for appointment staff, a screen (red triangle) to show how many documents are in the financial and pharmacy process or show the financial department how many non-w patient documents pass to the pharmacy, and the name so they can do the preparation work before P2 pharmacist finish the medicine preparation work. However, the work is still limited to online prescriptions, while for handwriting, they have to wait for sticker printing staff to key the details first.

Although there is still a delivery process, the distance is very short, only about five meters from the location to the pharmacy, and the nurse aid must come to this location to get an appointment card to find the patient so that this process can be done simultaneously. In particular, the placement of documents will be correct, like in the interview, because all the documents for finance have been taken out.

Set 2

The second design uses the same working process as set 1. However, it changes the location from a more visible location to a more accessible one for finance and pharmacy (Fig. 28).

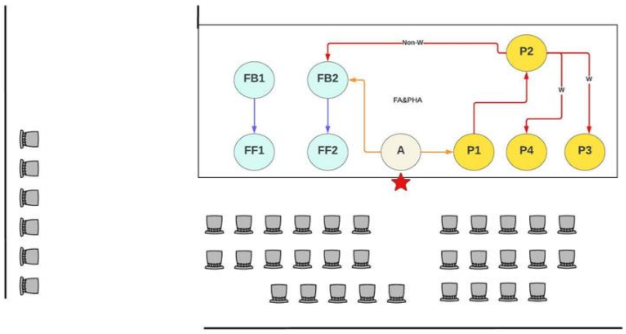


Fig. 28. Set 2 working environment.

Compared to the first set, the advantages and disadvantages of this design are;

<u>Advantage</u>

- With ECRS logic, combine the process of checking, sorting, and transferring documents to a convenient location to pass them. When receiving documents within the scope of work, the staff can give the financial-related documents on the right and the prescription on the left.
- Can understand, record, and help solve the troubles and understand the working methods of other departments.

<u>Disadvantage</u>

- The location is not apparent, and the patient may have a harder time finding it.
- Since the two departments are only connected by a small window, transferring files will fall to the person in this position.

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6.5. Problem 3 Analysis and Approach

The third question will revolve around how to solve the communication efficiency of the daily operation of OPD mentioned in Section 4. It is necessary to start from two aspects: internal and external communication. This section will mainly focus on strengthening internal communication.

6.5.1. Online staff dashboard

It is one of the tools that will support each staff member about whom they can ask in total. As shown in Fig. 29, It will bring different team staff information to a single page. So that it is easy for internal staff to see and can be interpreted briefly in the blink of an eye; when the staff dashboard can be updated in real-time, it can show the coverage gap and help management respond quickly in the event of unexpected shortages.

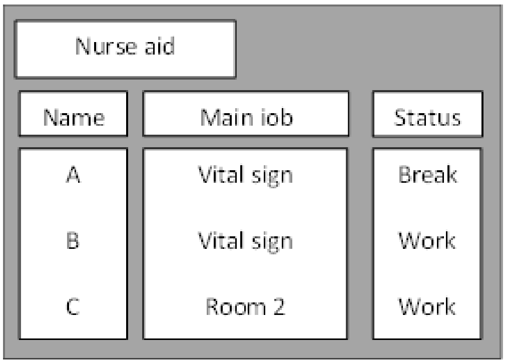

Fig. 29. Example of online staff dash board.

6.5.2. Poka-Yoke

This concept can also be applied to risk management for health services in hospital management by controlling, shutting down, and warning the error that happens in the system. This proposal aims to provide an easy-to-use installation and is part of the workflow foolproof idea.

The first set is the Colour Code System and Sensor-Colour Code Alignment. The outpatient already has this system to identify the patient type by folder colour. However, after the doctor's room, due to the delivery of the document with nurse aid, the paper must be separately delivered, causing the error of putting it into the wrong basket. The suggestion in this issue is to create a new colour folder to act as the document's destination inside.

Fig. 30. Example of colour folder.

The example is shown in Fig. 30; the nurse aid can know whether the document has an appointment or has medicine by colour.

The basket can install a small colour sensor (Fig. 31); if it detects a strange colour, the light will turn on and act as Andon for the staff.

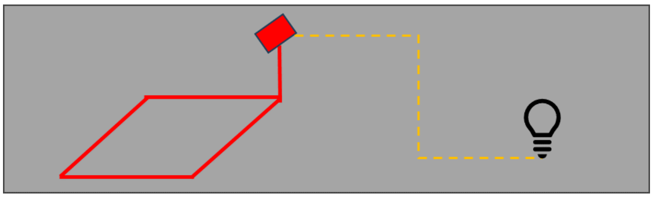

Fig. 31. Sensor on document rack.

The above suggestion assumes no changes have been made to the current process if NA is removed. In a situation without the nurse aid delivering, by letting the patient hold this folder, the staff around the department will know the status and provide the quickest support. This colour will also support the new team sorting time. They can act as part of a Two-Person Verification system where the staff at point A in Fig. 32 can check whether the document inside corresponds to the folder's colour. Then, the staff who received the folder from point A can recheck them, as the internal inspection of the pharmacy achieves two sets of eyes confirm. If the document proceeds after this process, the cost(time) each staff member must spend is higher.

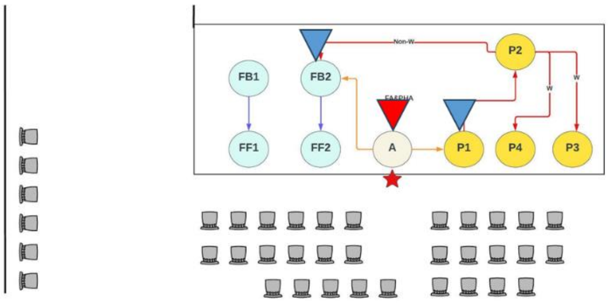

Fig. 32. Two-person verification system location.

The second suggestion is barcode scanning; before handling the folder to the patient, the nurse aid can scan the barcode in the document or folder to register to the system that the document left the examination room; when the folder arrives at the dropping point, the staff will be scanning the barcode again. This method works as a document tracking system to check whether the patient has received the folder and delivered it already; if the folder takes too long, the staff can ask closet roaming

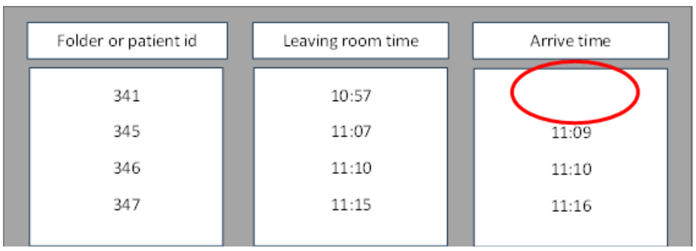

Fig. 33. Example of document tracking screen.

nurse aid or we care to check the patient's situation (Fig. 33).

In the patient visit information received from the hospital, the time recorded in the system includes the arrival time and enter and exit examination room time only; with this system, there will be a new column where the patient enters the appointment, pharmacy, and financial process (Fig. 34). Moreover, if the barcode scanning system can link with the patient ID, the hospital can collect the data on the estimated time the patient waits after the examination room process.

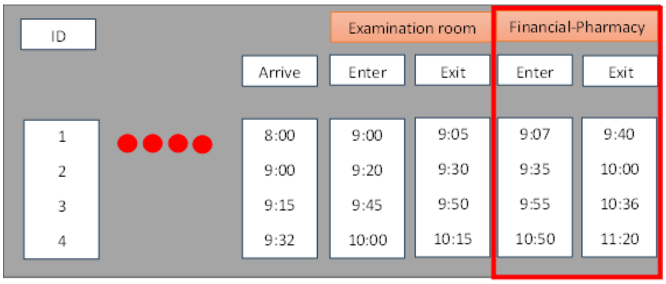

Fig. 34. New data column from the optimization.

6.5.3. Visual control

Conditions or needs of arriving patient

The faster they got identified, the faster the service provided. The level of precautions required for patients can identify with the symbol from the appointment paper when they are carried in or from the document that wecare prepare. The purpose is on the top right corner, put the symbol to help the staff at the entrance know what they should prepare.

Square: Fall-risk patients
Triangle: Allergies or special care requirements
Circle: Infectious, requires extra precautions
No symbol: Standard patient

Patient Pathway Signage

Signage that refers to directions is about more than colour or arrows sicker on walls; hospitals do not need to do all mentioned, but at least can support the patients in acknowledging where they have to go. Looking at the entire OPD, if we remove the staff shipping documents, the first thing to consider is letting the patient find the correct window. It can be improved by installing small lights on the sign. Another suggestion is that the colour near the window can be slightly modified without breaking the appearance. The financial and pharmacy departments are viewed from the front (Fig. 35)

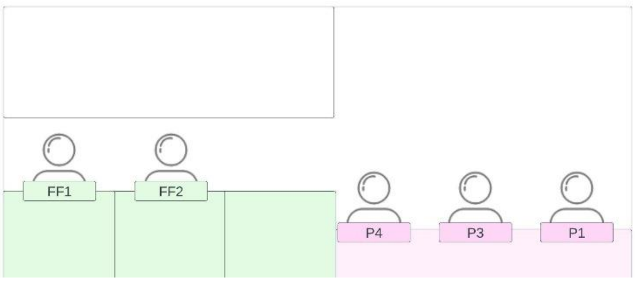

Fig. 35. Financial and Pharmacy counter front view.

Before adding the new counter, the pharmacy and financial could easily be identified by the tall counter, where the financial process, the patient has to stand at the counter and sign the paper or pay the bill. In pharmacy, the patient will sit in front of P3 and P4 when receiving the medicine. The colour tone of each zone can also be identified as a green tone in financial. However, if the appointment table needs to be here, the two mentioned positional comments can be modified using the spare financial window.

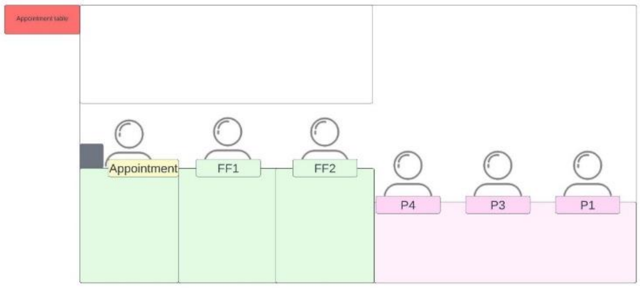

Fig. 36. Set 1 layout counter design.

The first set of designs is shown in Fig. 36. Because the window is on the farthest side, as long as the sign is placed on it, it will be easy to see the patients in the two corridors. When guiding the way, they can also say "the leftmost window", and because there will be a document rack in this position, the window will be seen.

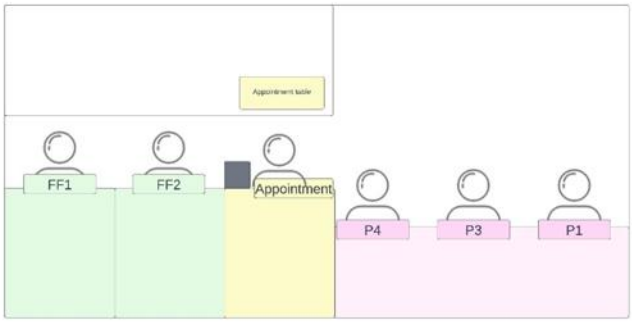

Fig. 37. Set 2 layout counter design.

On the contrary, the second window between the two departments needs more prompts for the convenience of file transfer (Fig. 37). Adjust the lower part of the window to a colour suitable to be placed with green (in this case, yellow); it is difficult to change the upper part because it is connected. In order to be seen by people passing by the corridor, a sign saying "OPD2 finance and pharmacy" attached to the ceiling in Fig. 38 will help people from rooms 15 and 16 direction know that this is where they are coming from. If the patients come from the front, they can directly distinguish it from the colour because nothing is blocking it.

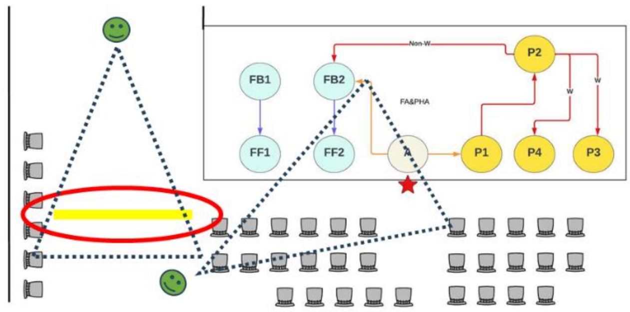

Fig. 38. Colour signage support in guiding the patient.

In this chapter, in addition to the literature reading, the method of benchmarking against other hospitals is used to find a suitable solution to the hospital's existing problems in section 4. Propose root cause analysis and propose an optimisation plan according to each problem.

The first problem focuses on quantitative data, proves where the problem is through SIMIO, proposes a solution, and checks whether the solution affects other departments. Demonstrate the use of Lean theory on the operational side, reducing several factors that cause errors or prolong the internal process, which leads to excessive waiting time.

In the second question, SIMIO software is also used to prove the effect of human resource efficiency in various places and propose the benefits and limitations brought by modifying, deleting human resources, and adjusting steps. Provide a new discussion of the positive and negative effects of the layout.

The third question is the internal communication optimisation method and the content that needs to be done or prepared to keep up with the proposal in the former two topics.

7. Conclusion

7.1. Summary

With the aim to improve hospital operations, this paper studied merging simulation techniques with Lean principles, demonstrating how the two approaches can increase operational effectiveness, streamline procedures, and promote continuous improvement. The following is the research's primary focus. This paper went through a comprehensive review of literature, interviews, and on-site observations. Then, summarised the data on how the hospital deals with the daily problems. The data collection method was designed to gather qualitative and quantitative data for analysis and simulation purposes, resulting in three core problem findings.

1) Doctors leave the examination room during the congested period, especially in the internal medicine group.
2) There are no staff to collect the documents and deliver them to the pharmacy, which makes documents delivered to the pharmacy come in batch.
3) Sticker printing manpower is not enough in a specific period.

Hence, the SIMIO simulation software is used to model and simulate the outpatient department, utilising the software's process steps to delineate the functions of each team within the department and assess the simulation system to find out and prove the existing problems of the system cause the bottleneck, which resulting in longer waiting times in outpatient.

This paper also conducted a benchmarking with other hospitals about three main ideas that can be adapted to the research hospital, which is:

1) Set the doctor's leave time policy and train the team to support each bottleneck location in peak periods.
2) Use visual management to support both internal and external processes.
3) Create a system to check the document details and location. Reduce the time document waiting in the system without any process.

Then, proposed methods to decrease the waiting time and optimise the model in this paper. The optimisation model consists of

1) Two sets of doctors leave schedule (L11 and L12) to reduce the waiting time and document batch size to the latter Process.
2) The two scenarios are adding more staff to deliver documents and removing delivering staff.
3) Adding pharmacy staff at specific times to reduce the time documents are waiting in the system.

After changing the data in the model, finally, through the data obtained by the experimental function in SIMIO, find the most effective model and compare the result.

Take the average time in the system of social security patients in Fig. 39 as an example; from 1999 second, through various optimisation and experiments, it can reduced up to 8% to 1820 seconds. And in the reduced time, it can also save the time of some personnel, allowing them to help other places.

While modifying the model, several Lean pieces of knowledge are used in the analysis, problem identification, proposal support ideas, and based on Lean, an optimisation idea for several outpatient locations. Root cause analysis is used to understand the reason for the bottleneck to reach the continuous improvement of the Lean framework and the method of increasing the throughput rate, such as Poka-Yoke, Self-check inspection, and One-stop station. Finally, ideas for improving workflow were introduced, such as Standardized work, Visual control, Flow cell, Heikunka (levelling), and Batch size reduction (or One-piece flow).

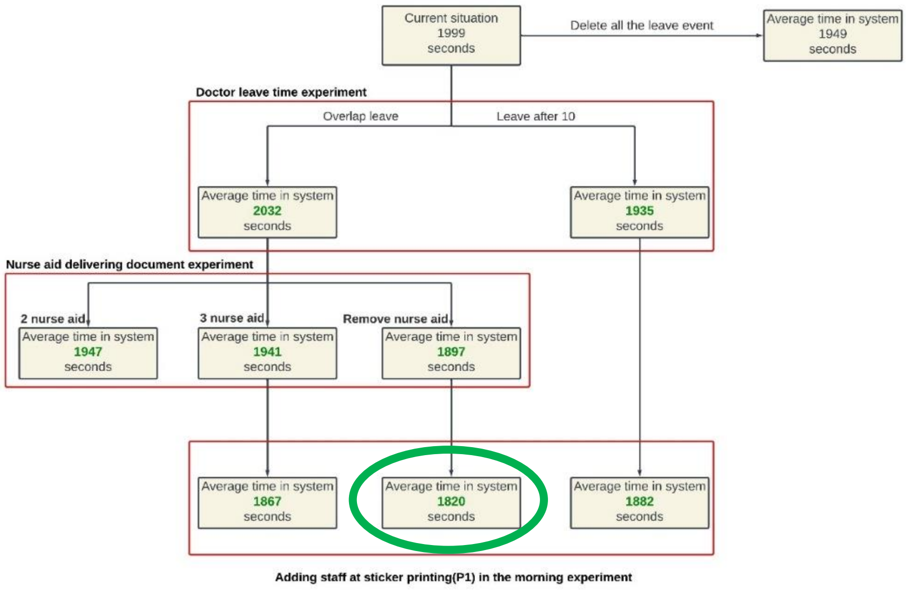

Fig. 39. The average time in the system of W type patient from SIMIO experiment.

7.2. Contributions and Implications

The paper emphasises how Lean integration may be used in various daily operation processes in healthcare. It contributes by giving healthcare administrators a potent decision-support tool and idea to locate the problem, restructure procedures, better allocate resources, and ultimately improve patient care. Additionally, simulations allow companies to acknowledge the problem in their system, find optimal configurations, be aware of potential issues, and create proactive plans. The simulation results show that the average time in the system of the patients decreased by 8%, which is a significant change.

The study's findings show a holistic approach to how Lean principles can foster an improvement within the healthcare field, with the support of simulation, demonstrate the potential capabilities of the optimisation method without interfering with ongoing business activities to preserve competitive advantage and ensure the smooth running of operations in the unstable business environment. To successfully deploy it, one must work with teams, invest in reliable simulation tools, and commit to promoting a culture of continuous development. In addition to improving process efficiency, this synergy makes it easier to allocate resources, reduce risks, and make strategic decisions.

7.3. Limitations and Future Research

While this study has provided valuable insights into the subject matter, it is important to acknowledge certain limitations that may have influenced the outcomes and interpretations of the research.

1) The quality of the information provided significantly impacts the simulation results' accuracy. Flaws or errors in data sources may impact the dependability of results. The data in some locations was limited due to time constraints for both interview samples and the number of data points. A larger sample size could yield more comprehensive and nuanced findings.
2) In the data collection, researchers cannot enter and observe in several locations because of the display of patient information, or only hospital staff can enter. So, only the time of entry and exit of documents is recorded and observed, resulting in the inability to propose Lean tools on several processes.
3) Although the essential functions of the simulation model have been realised, there are details to be improved in the actual process. The first is the logic of the arrival of patients. Now, the patients are randomly allocated according to the percentage. However, in reality, sometimes a large number of guests may come, and sometimes no one will come.
4) The study was limited to specific geographical and cultural of medium size hospital situations. The proposed solutions and tools may only be suitable for some backgrounds.

For future research, executing the long-term research plans from weeks to months to quarterly and annual to provide a more comprehensive view of the phenomenon. Once long-term research can be done, collecting more content from private locations can lead to better optimisation methods. Future studies could use more sampling methods to ensure a more diverse and representative sample of participants.

A complete simulation can be further designed, such as each department's internal file processing steps or the simulation of the situation on the weekend's patient arrival and doctor shift, which is more complicated. Further, it explores the usability and cost-effectiveness of several proposed solutions for different environments and cultures.

Since some screens or systems cannot observed to ensure privacy, in future research, more study and pivot projects can focus on computerised communication systems. Regarding effective communication, because simulation and Lean tools cannot realise or demonstrate some functions of this aspect, the research optimisation proposed can only be the idea that can be observed.

The hospital already has sufficient hardware, software, and network infrastructure; outpatients can reduce the use of documents step by step and convert them to online documents. For example, all drug orders must be ordered on the computer, and a simplified drug selection screen must be established. The method allows finance and pharmacies to receive online information simultaneously. They can check and provide feedback on problems in advance to reduce the behaviour of passing the question around and reduce unnecessary processes.

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