Research Article

Enhancing Capacity Planning through Lean Principles and Simulation: A Case Study of a Local Hospital in Thailand

Wannalak Laotaweesub*
Department of Industrial Engineering, Faculty of Engineering, King Mongkut's University of Technology North Bangkok, Bangkok, Thailand

Nantakrit Yodpijit
Center for Innovation in Human Factors Engineering and Ergonomics, Department of Industrial Engineering, Faculty of Engineering, King Mongkut's University of Technology North Bangkok, Bangkok, Thailand

Juthamas Choomlucksana
Department of Materials Handling and Logistics Engineering, Faculty of Engineering, King Mongkut's University of Technology North Bangkok, Bangkok, Thailand

Manutchanok Jongprasithporn
Department of Industrial Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand

* Corresponding author. E-mail: wannalak.l@cit.kmutnb.ac.th DOI: 10.14416/j.ijast.2018.03.003
Received: 2 May 2017; Accepted: 23 June 2017; Published online: 23 March 2018

Abstract
Healthcare improvement is complicated and has become public concern in Thailand during the past decade. The purpose of this research project is to improve the quality of healthcare and patient satisfaction utilizing Lean principles. This research is conducted in a middle-sized Pluakdaeng hospital in Rayong, Thailand where there are approximately 364 patients daily under the supervision of 6 doctors, 6 pharmacists, 53 nurses and 124 supportive staffs. In Lean studies, computer simulation and Value Stream Mapping (VSM) are utilized to define and eliminate wastes in the hospital business process. Findings indicate that service rate at the hospital can be increased to 28.98% and the average patient waiting time can be reduced to 28.65%. Future work, improvements, limitations and suggestions on the current research are also provided and discussed.

Keywords: Healthcare, Patient satisfaction, Lean, Value Stream Mapping (VSM)

1 Introduction

Lean management is a series of operating philosophies that maximize efficiency of any processes. It aims to change behavior of organization and leads to culture sustainability changed. Its success is long known in many industries especially in automobile industry. Based on the Toyota model, it focuses on how efficiently resources are being used and ask, 'what value is being added for the customer' in every process [1], [2]. The study Lean in healthcare, found that Lean has been recognized by public services as well as health care. Central government and local government organization applied to the organization found that defining lean

Please cite this article as: W. Laotaweesub, N. Yodpijit, J. Choomlucksana, and M. Jongprasithporn, "Enhancing capacity planning through lean principles and simulation: A case study of a local hospital in Thailand," *KMUTNB Int J Appl Sci Technol*, vol. 11, no. 2, pp. 117–125, Apr.–Jun. 2018.

with each research article. Is not the same, the core of Lean's philosophy is to develop a method by eliminating unnecessary steps [3]. Application of Lean principles in healthcare, in particular a hospital, should remove duplicate processes and unnecessary procedures.

Using Lean theory for improving workflow and applying lean tools to detailed work processes; in addition, mental health service areas of elderly patients. The Rapid Process Improvement Workshops are scheduled to be operational and reported within 90 days. The results from chief nurses in all departments and senior nurses of the two-day waiting time reduction program are expected to be within 1–5 days. The rate of referrals is increased from seven to twenty. Desk facilities can be tracked and coordinated by the health IT systems. It is required to log in every time a nurse enters a ward [4].

VSM is one of a tool in Lean principle. It is a collection of all actions including both value added and non-value added that are required to bring a product or product family using the same resources through the major flow, starting with raw material until ending with customer. The removal of waste to reduce the non-value process from the process. Information system of the sanatorium analyzes data from site observations, interviews, and workflows to eliminate waste from the process; in addition, the application of value stream to identify problems and develop solutions. These include: organizing, maintaining, integrating, and standardizing procedures into nursing information systems. The uniqueness of this mapping method simplifies visualization of the cycle time, inventory at each stage and also human effort together with information flow [5].

Recently, the health care service has demonstrated success in applying these principles in the United States, United Kingdom, Australia and Canada [2], [6], [7]. Lean management has been applied in health care process improvement. Many researches [7]–[9] regarded its implementation to be practical, fitful and partially applicable. Although research on its application and sustainability in health care was wide spread, well understanding was still limited yet explicit. Previous studies often lacked appropriate conceptual approach, research designs, consolidate analysis and well outcome measures [10]. Most studies reported on successful lean application; whereas, a few reports have been acknowledged on the failed attempts or barriers to its implementation in health care. It is therefore imperative to classify and conceive the previous works systematically. The effects of lean implementation especially on clinical workplace and health care are still doubtful. The research has applied the principle of lean to the internal information system of the heart disease clinic. Using VSM and A3 problem solving to eliminate non-value activities along with data and workflow improvements, including improvements in workflow, 67.64% in value-added activities, 32.36% in non-value-added activities, and a process flow chart for the future. A3 paper of Intra-operating management process to clearly visualize the work [5].

The following literature review demonstrates the use of mathematical models to improve patient flow and to make the best schedule. The design and development of the Discrete Event Simulation (DES) Model based on Object Oriented Paradigm (OOP) has been described in a study for a physician operating area. The results show that simulations in a virtual environment can help in displaying and presenting analytical results. This model makes it possible to visualize the detailed mechanism of the treatment area. This encourages decision-makers to make informed decisions.

DES technique is a model based on the OOP. The model is generally used to simulate work processes which have high degree of freedom. The technique is sufficient to dynamic, random, variable and uncertain process and applied to use Discrete-Event Stochastic (DES) as a decision support tool. The scheduling of the doctor's work is divided into 3 periods: morning, afternoon, and evening, by simulating the patient's attendance at each session. It also determines the number of physicians and extends the physician's time at each interval to accommodate patients, reduce patient waiting times, simulate the situation by increasing the number of patients by 50% and schedule a doctor's work to support the situation [11].

There are many research works that bring HEF knowledge to business operations by bringing the science of human interaction to the elements of work as a strategy to optimize business competition. By targeting is to maximize employee productivity overall system performance. By designing a work environment that fits well with both employees and systems. The results have been successful in terms of effectiveness, quality,

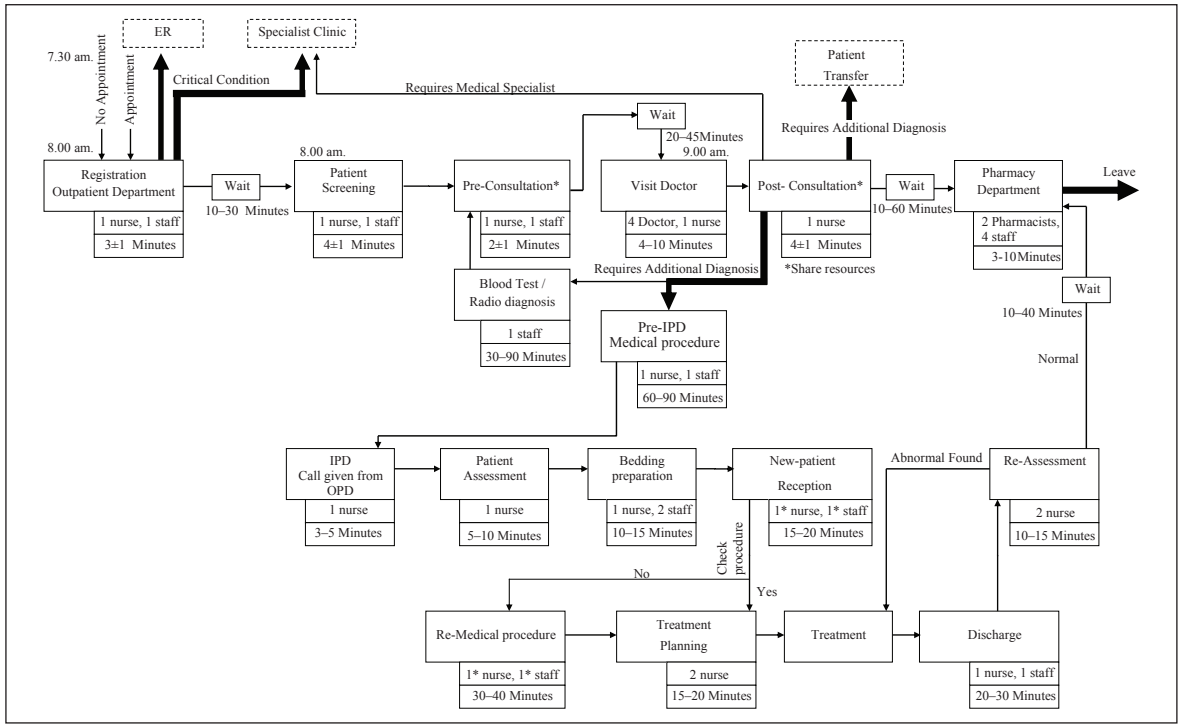

Figure 1: The OPD and IPD workflow at a Local Hospital in Thailand.

health and safety including employee satisfaction on learning and self-improvement [12]. DES model also used to investigate the real causes in the winter bed crisis problem. The study of the winter bed crisis occurred every year during Christmas in British hospitals. Potential causes were assumed to be the bad weather, influenza, older people, geriatricians, a lack of cash and nurse shortages. Another potential source could be that beds within the hospitals were blocked due to lack of social services for discharge hospital patients during the Christmas period. The results showed that staff leave and public holidays were a possible explanation of the winter bed crisis and emphasis that influenza can be excluded as a reason [13].

DES was also used to test the impact of new services offering to older patients. This case study determined system capacities, and investigated potential care pathways after discharging from hospital by simulation model. One aim of this model is to estimate the reimbursement costs [14].

A case study is a community hospital with 30 beds-size, located in the industrial park. The hospital has the doctor/population ratio–1 : 8,867, in addition, the nurse and staff/population ratio–1 : 1,400. The current service rate of outpatient and inpatient is in between 300–500 persons a day. The analyzed information based on nurse head and nurses in OPD and IPD together with service information from October to November 2016 can be concluded to be the OPD and IPD workflow shown in Figure 1:

OPD gets patient queuing at 7.30. The registration starts at 8.00 for individual patient demographic assessment and vital sign measurement which has 1 nurse and 1 staff officer. The waiting time is found between 5–30 minutes at patient assessment waiting point.

Patient Screening starts at 8.00. This process includes information filling, patient-record searching, medical rights verifying and medical right writing/signing on form i.e. personal insurance, 30 baht-golden card social security, company welfare, foreign insurance (AEC labors). There is medical certificate writing process which has 1 nurse, 1 staff. The waiting time is found between 5–30 minutes at this point.

Doctor Visiting starts at 9.00. It is a doctor consultation based upon symptoms. It is found that each one has an average of 4–10 minutes per case/patient.

Table 1: Current state time schedule of staffs

Registration 08.00–16.30	Screening 08.00–16.30	Pre-Consultation 08.30–16.30	Diagnostic Room 09.00–16.30	Post-Consultation 09.00–17.00	Pharmacy 09.00–17.00
Nurse 1* 08.00–12.00 13.00–16.00 Staff 1 08.00–12.00 13.00–16.00	Nurse 2 08.00–12.00 13.00–16.30 Staff 2 08.00–12.00 13.00–16.30	Nurse 3* 08.00–11.30 13.00–16.30 Staff 3* 08.00–11.30 13.00–16.30	Doctor 1, 2, 3, 4 09.00–12.00 13.00–16.30	Nurse 4 09.00.00–12.00 13.00–17.00 *Share Resource	Pharmacist 1 09.00–12.00 13.00–17.00 Pharmacist 2 09.00–12.00 13.00–17.00

Post-consultation has nurse filling in the data, making a prescript on record, and taking the patient to pharmacy department. If further physical examination is required, nurse will transfer blood testing/x-ray with accordance to doctor's control. When those results are received, the patient will return back to doctor consultation. The waiting time is found between 5–15 minutes.

Lab Testing is needed when further physical examination is required by the doctor. In case there is no lab testing is required, the patient takes the prescription and invoice to pharmacy department. Patient will then wait to be called between 10–30 minutes. After paying the medical bill, patient needs to wait to be called at pharmacy department between 10–60 minutes.

IPD occurs when the doctor requires the patient to have further treatment as inpatient. Post-consultation will prepare medical treatment according to doctor's instruction and call IPD in order to inform patient's record and medical treatment.

Discharge happens when patient recover. The records of the patient's treatment provide the recovery information i.e. discharge planning, scheduling for medical appointment, invoice and prescription preparation to the patient and his/her family, the patient's family is informed regarding the medical bill and get medicines at pharmacy department.

Pharmacy Department is a final point which receives patients from all wards before going home. Therefore, this point is considered highly important for service rate.

1.1 *Current state time schedule of staffs*

The service hours of OPD staff during Monday–Friday. Number and service hours are demonstrated in Table 1.

1.2 *Arrival rate*

Due to the uncertainty of service rate, the hospital records

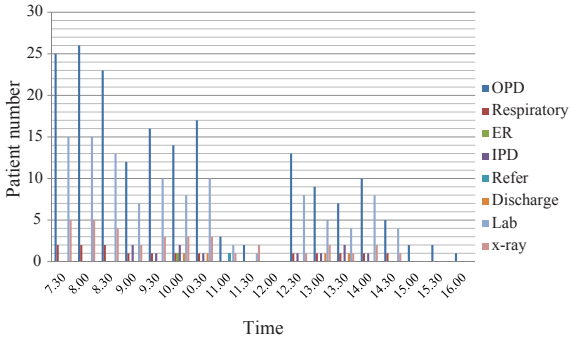

Figure 2: Patient number classified by time and patient type of services.

show number of patients divided by type of services. The OPD patients can be divided into 8 categories and counted every 30 minutes each day for 30 working days as shown in Figure 2.

According to patient interview, meeting with hospital staffs, cause and effect categorization, patient's flow-rate and service rate analysis, the Current State Value Stream Mapping was formed in order to analyze the capacity planning.

2 Enhancing Capacity Planning with Simulation

The lean principle and DES approach show similarity process. Therefore, the combination of these 2 approaches is presented and the research can be divided into 5 steps as shown in Figure 3.

The information needed, to construct the Current State Value Mapping in order to analyze capacity planning using ARENA Rockwell Software, was taken from patient interview, meeting with hospital staffs, cause and effect categorization and patient's flow rate and service rate analysis shown in Figure 1. Arena has been widely used in various fields of simulating such as manufacturing, logistics, transportation, warehouse

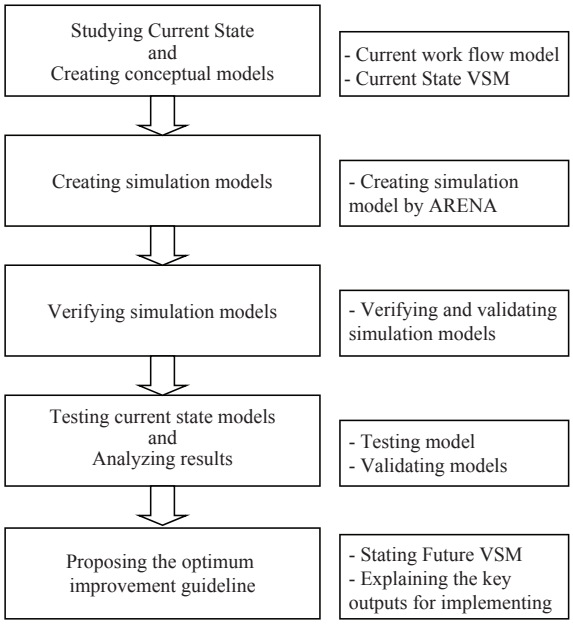

Figure 3: Lean and DES 5 Step Research.

etc. Not only simulating, but also calculating statistical behavior of sample group so called Input Analyzer. Input Analyzer has input variables in a form of stochastic variables. Hence, the basic simulation model was developed based on logical workflow which shown in Figure 1 as conceptual model. Figure 4 presents the current state models of OPD simulated by ARENA.

The model was validated by using percentage of parameter deviation and t-test, which was the validation test according to ARENA book [15]. The validated model fixed service rate and reduced patient's waiting time by extending service time from 8.00–16.30 to 7.30–17.00. However, the doctors' consultation time remains the same (9.00–16.30). Transferring nurse 4 from Post-consultation to work in Screening point at 8.00–9.00 and transferring nurse 1 from registration point to work in Post-consultation at 16.30–17.00. The staff from registration was moved to Pre-Consultation at 16.00–16.30. One staff need to be added at pharmacy department during 12.00–17.00 as shown in Table 2.

3 Current State VSM

The result of Current State VSM has been widely used to identify problems in OPD system in term of waiting time, waiting numbers and resource utilization. In this VSM, many problems are found. They are categorized into 2 main problems; 1) Average waiting

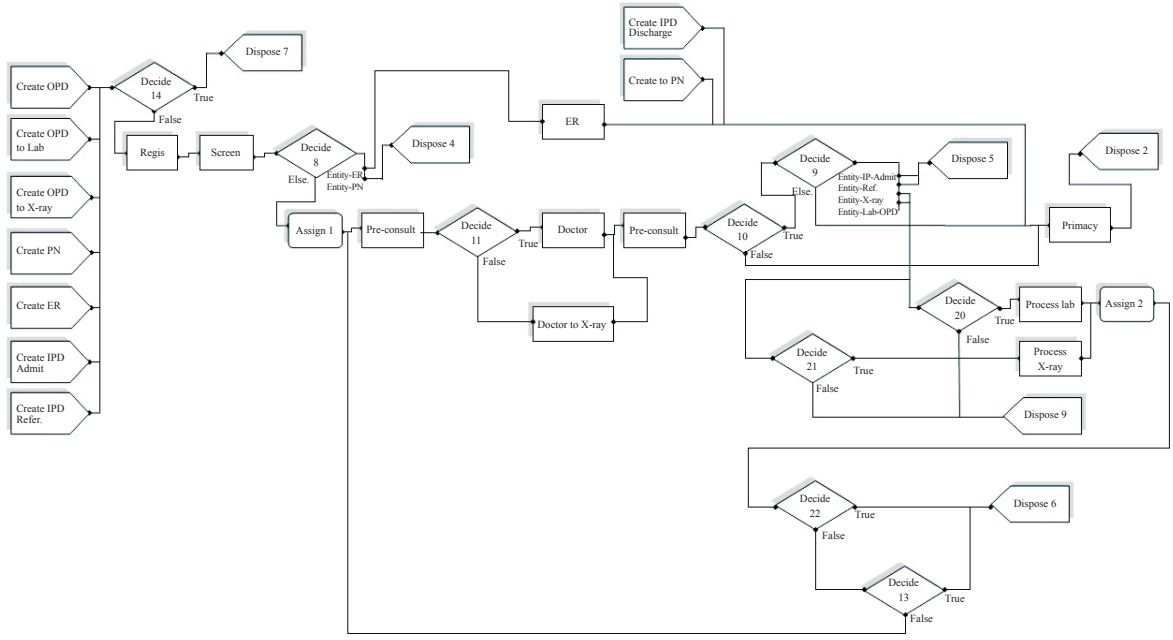

Figure 4: Current state models of OPD simulated by ARENA.

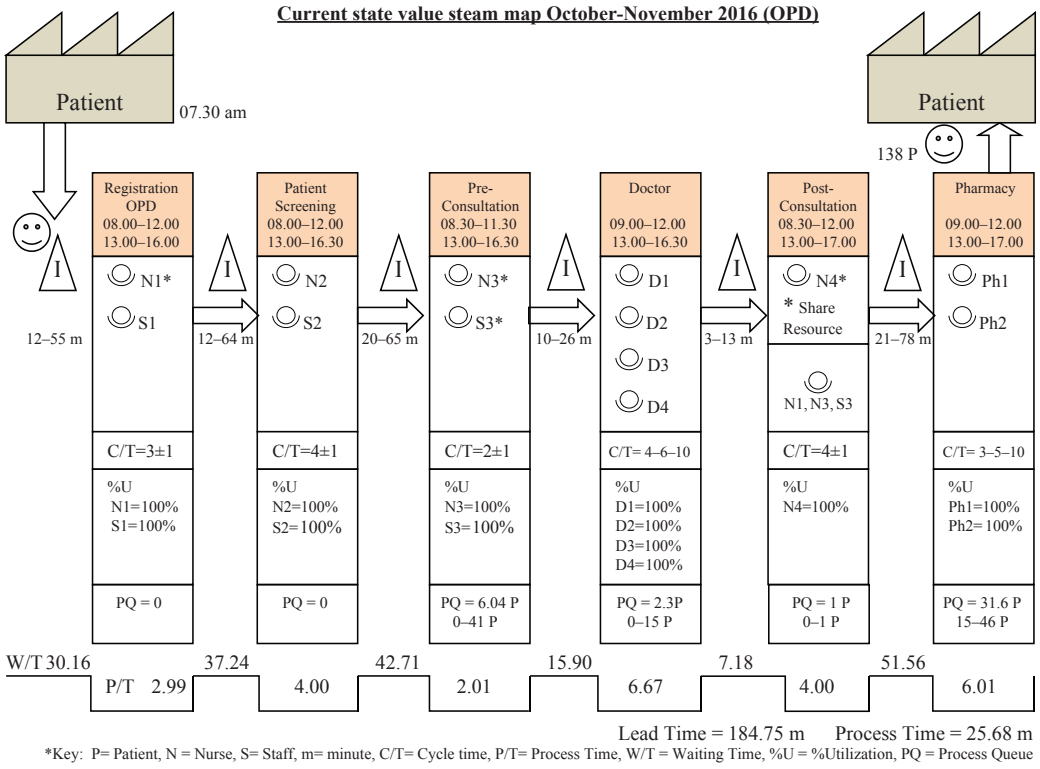

Figure 5: Current State VSM.

Table 2: Future state time schedule of staff

Registration 07.30–16.30	**Screening 07.30–16.30**	**Pre-Consultation 07.30–16.30**	**Diagnostic Room 07.30–16.30**	**Post-Consultation 09.00–17.00**	**Pharmacy 09.00–17.00**
Nurse 1*	Nurse 2	Nurse 3*	Doctor 1, 2, 3, 4	Nurse 4	Pharmacist 1
07.30–12.00	07.30–12.00	08.00–11.30	09.00–12.00	09.00–12.00	09.00–12.00
13.00–16.30	13.00–17.00	13.00–16.30	13.00–16.30	13.00–17.00	13.00–17.00
				*Share Resource	Pharmacist 2
Staff 1	Staff 2	Staff 3*			09.00–12.00
07.30–12.00	07.30–12.00	08.00–11.30			13.00–17.00
13.00–16.30	13.00–17.00	13.00–16.30			
Nurse 4		Staff 1		Nurse 1	Pharmacist 3
08.00–09.00		16.00–16.30		16.30–17.00	12.00–17.00

time and 2) Patient queue in process.

The waiting time occurred at registration screening and pre-consultation are in between 12–55 minutes, which lead to the number of patient to ward equal to 185 persons. The average waiting time at pharmacy department is 51.56 minutes. The patient in the system can be found in pre-consultation, post-consultation, doctor-consultation and pharmacy department at the rate of 41, 1, 15 and 46 persons respectively at the time of 17.00. The lead time is 184.75 minutes and process time is 25.68 minutes. There is 138 patients can be out of the system by running 100 replication. It is shown in Figure 5 and simulation of OPD services shown in Figure 6.

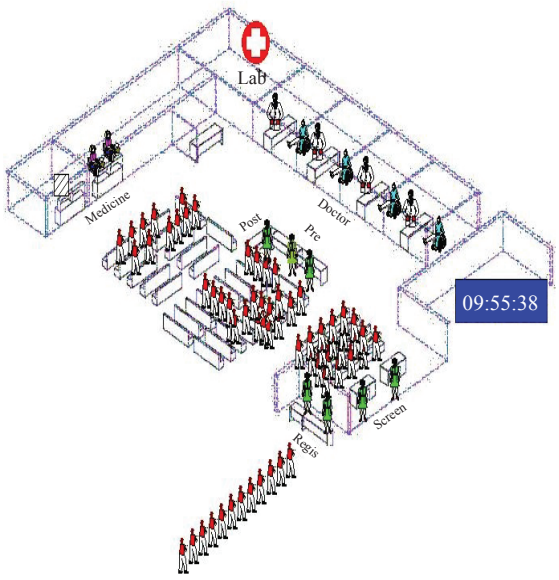

Figure 6: Simulation of OPD services.

4 Analysis and Comparison of Different Capacity Planning

As current VSM shows the waiting time and service rate problem, the capacity planning experimental design is conducted that not affected on working system, man and working hours. Three alternatives capacity planning is created to compare the long waiting time point as shown in Table 3.

Plan 1: Increasing nurse's service hours in registration and screening by starting at 7.30 and ending as usual at 16.00.

Plan 2: After increasing nurse' service hours according to plan 1, the pharmacy department's service hours also increases 1 hour by starting at 9.00 and extending closing hours at 17.00. And also adding 1 staff during 12.00–17.00, the reshuffle is implemented. Post-consultation's service hours are increased by shuffling nurse 4 to work in registration during 8.00–9.00 and extend service hours to 17.00. The Staff 1 in registration is transferred to Pre-consultation during 16.30–17.00. The nurse 1 from registration is also transferred to work in Post-consultation during 16.30–17.00.

According to the experimental result, plan 2 gives the best result. Therefore, plan 2 is purposed to be an improved working system model for OPD ward in order to have more working efficiency and not affect the doctors' schedule.

5 Future State VSM

The analysis of current state VSM shows that adjusting service time to 7.30, staff shuffling, sharing resource, transferring staff when patient is crowded and adding 1 staff at pharmacy department during 12.00–17.00 reduce waiting time in registration between 1–20 minutes screening and pre-consultation between 8–68 minutes. It can be decreased 40.46% from the highest waiting time and lead to increase waiting time for doctor consultation to 57.70%. The highest waiting time in pharmacy department can be decreased 35.90%. At 17.00, the patient in the system can be found in pre-consultation, doctor-consultation and pharmacy department at the rate of 2, 26 and 12 persons respectively at the time of 17.00. The lead time is 131.53 minutes and process time is 25.64 minutes. There is 178 patients can be out of the system by running 100 replications as illustrated in Figure 7.

Table 3: Comparison of three alternatives with capacity planning consideration on waiting time

	Current VSM (Minute)	Plan 1	Plan 2
Waiting time at registration	30.16	11.12	4.79
Waiting time at Screening	37.24	24.5	31.08
Waiting time at Pre-consultation	42.71	44.25	28.25
Waiting time at Diagnosis Room	15.90	22.80	31.24
Waiting time at Pharmacy Department	51.56	62.45	26.96
Number of Patient Out (persons)	138	138	178

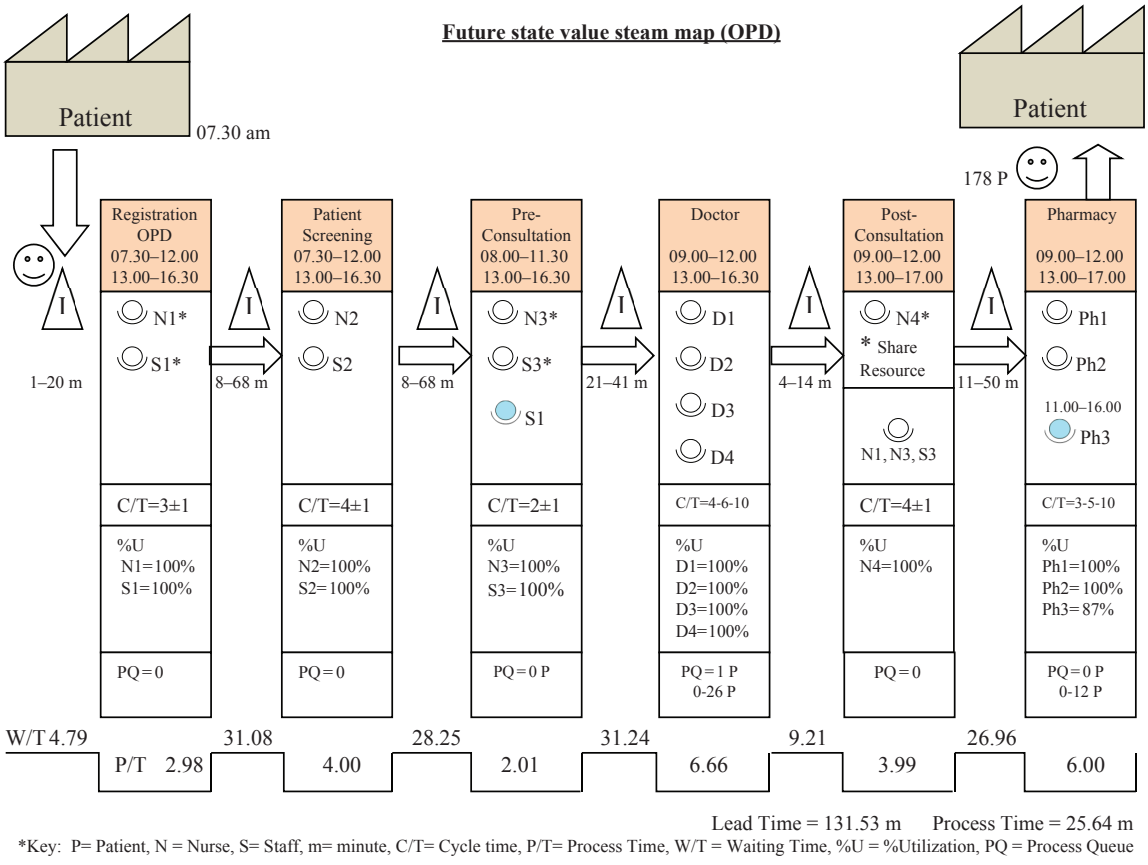

Figure 7: Future States VSM.

6 Conclusions

Lean principles and computer simulation techniques are highly effective approaches for investigating work systems. It is able to confirm the improvement work system in order to schedule operation process, adjust human resource, enhance work efficiency, identify working hours and reduce waiting time. The major factor of model simulation is to show efficiency of healthcare operations by adjusting work flow and performing current VSM. It leads to the improvement of work system from future VSM to capacity planning. The increasing of an hour in service hours (7.30–17.00), sharing resources and reshuffles when crowded and not interfering with doctors' schedule lead to an enhancement of 28.98% of service rate and reducing average of 28.65% of patients' waiting time.

Though, this research tested OPD work load and identified waiting problem. The lack of human resources, the staffs' stress and fatigue, service attitude, staff development and working facilities problem still occurred. Those mentioned problems affect working efficiency of the staff. Those problems not only influence on service receiver' satisfaction, but also hospital environment. Therefore, they need to be considered in order to enhance efficient work and service efficiency of the hospital.

Acknowledgement

Authors would like to express our sincere gratitude to the physicians, pharmacists, nurses, technical/ medical assistants, and supportive members at Pluak Daeng Hospital in Rayong, Thailand for their great contributions on data collection and analysis for this research project. Our special appreciation goes to Assistant Professor Naratip Sangsai of Mechanical Engineering Technology Department, College of

Industrial Technology at King Mongkut's University of Technology North Bangkok for his technical advice and support on computer simulation techniques.

References

[1] John Black and Associates. (2014, Sep.). Lean leader certification and maintenance-Physician Track : Frequently Asked Questions (FAQs) John Black and Associates. Canada [Online]. Available: https://www.sma.sk.ca/kaizen/content/files/2013-09-03LLTFAQ.pdf

[2] R. J. Campbell, "Thinking lean in healthcare," *Journal of AHIMA*, vol. 80, no. 6, pp. 40–43, 2009.

[3] Z. J. Radnor, H. Matthias, and W. Justin, "Lean in healthcare: The unfilled promise," *Social Science & Medicine*, vol. 74, pp. 364–371, 2012.

[4] P. Attkinson and E. B. Mukaetova-Ladinska, "Nurse-led liaison mental health service for older adults: Service development using lean thinking methodology," *Journal of Psychosomatic Research*, vol. 72 , pp. 328–331, 2012.

[5] S. Khodambashi, "Lean analysis of an intra-operating management process-identifying opportunities for improvement in health information systems," *Procedia Computer Science*, vol. 37, pp. 309–316, 2014.

[6] G. Smith, A. Poteat-Godwin, L. M. Harrison, and G. D. Randolph, "Applying Lean principles and Kaizen rapid improvement events in public health practice," *Journal of Public Health Management and Practice*, vol.18, no. 1, pp. 52–54, 2012.

[7] B. A. Fine, B. Golden, R. Hannam, and D. Morra. "Leading lean: A canadian healthcare leader's guide," *Healthcare Quarterly*, vol. 12, no. 3, pp. 32–41, 2009.

[8] N. Burgess and Z. Radnor, "Evaluating Lean in healthcare," *International Journal of Health Care Quality Assurance*, vol. 26, no. 3, pp. 220–235, 2013.

[9] W. Ulhassan, C. Sandahl, H. Westerlund, P. Henriksson, M. Bennermo, U. von Thiele Schwarz, and J. Thor, "Antecedents and characteristics of lean thinking implementation in a Swedish hospital: A case study," *Quality Management in Healthcare*, vol. 22, no. 1, pp. 48–61, 2013.

[10] P. Mazzocato, R. J. Holden, M. Brommels, H. Aronsson, U. Backman, M. Elg, and J. Thor, "How does lean work in emergency care ? A case study of a lean-inspired intervention at the Astrid Lindgren Children's hospital, Stockholm, Sweden," *BMC Health Services Research*, vol.12, no. 28, pp. 1–13, 2012.

[11] W. Waressara, P. Juta, and S. Peerapong, "A generic discrete-event simulation model for outpatient clinics in a large public hospital," *Journal of Healthcare Engineering*, vol. 4, no. 2, pp. 285–305, 2013.

[12] J. Dul, R. Bruder, P. Buckle, P. Carayon, P. Falzon, W. S. Marras, J. R. Wilson, and B. van der Doelen, "A strategy for human factors/ergonomics: Developing the discipline and profession, *Ergonomics*, vol. 55, no. 4, pp. 377–395, 2012.

[13] S. Dodds, "Designing improved healthcare processes using discrete event simulation," *British Journal of Healthcare Computing*, vol. 22, pp. 14–16, 2005.

[14] K. Katsaliaki, S. Brailsford, D. Browning, and P. Knight, "Mapping care pathways for the elderly," *Journal of Health Organization and Management*, vol. 19, pp. 57–72, 2005.

[15] W. D. Kelton, R. P. Sadowski, and N. B. Swets, *Simulation with ARENA*, 5th ed. Singapore: McGraw-Hill, 2010, pp. 631.