International Journal of Engineering & Technology, 5 (x) (2017) xxx-xxx

SPC

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi:
Technical paper

Effect of Lean Systematic Method on Specimen Handling Activities for Patients in Medical Wards

Noor Widasuria Abu Bakar[1], Abdul Hadi Mohamad[1,3]*, Pavan Kumar Jatavakabhulla[1], Shahrulniza Musa[1], Marzilawati Abd Rahman[2], Lee Fat Soon[2], Tan Seew Geek[2], Azahirafairud Abdul Rahim[2]

[1]*Malaysian Institute of Information Technology, Universiti Kuala Lumpur, Malaysia*
[2]*Department of Medicine, Hospital Kuala Lumpur, Malaysia*
[3]*Center of Excellence Geopolymer and Green Technology (CeGeoGTech), Universiti Malaysia Perlis, Malaysia*
**Corresponding author E-mail:abdulhadi@unikl.edu.my*

Abstract

Lean is a quality improvement methodology that can identify and eliminate waste from processes. While the methodology is widely implemented in manufacturing and automotive, it is also applicable to another area such as the service industry of healthcare. Institutions who concern with health, such as the hospital involve complicated and lengthy business process daily. Consequently, this encourages the exhaustive process chain, which is unreliable, cost ineffective and resource wastage. Moreover, the chain may lead to medication error or error in medication delivery. Although the Lean systematic method is widely used in healthcare, there is limited empirical evidence in resolving such issues, mainly focusing on specimen handling in a real hospital environment. This paper generally focuses on the implementation of a systematic method of Lean into a healthcare institution in Malaysia to decrease the time access and to have better inventory control of specimen. The adoption of Lean is achieved by implementing an efficient barcode system namely Specimen Labelling System (SPLS) for specimen handling to pursue better management, which will lead to time reduction and allow the hospital to offer good quality healthcare service. The study confirms that the systematic Lean method is significantly improved actions and processes. The finding is also applicable to lead to a general patient satisfaction by adding values to the existing process but shorten some additional activities.

Keywords: *agile software development, computer applications, lean, public healthcare, requirements engineering*

1. Introduction

The number of organisations with Lean thinking has been increasing every day. Successful Lean production practices result in several operational, financial, productivity and quality improvements. One way for companies to be more successful in markets is to focus on performance and quality. While some organisations continue to grow and stay competitive in the service industry, other are struggling due to maintaining a high-quality service within their organisation cost practices [1].

Due to these caveats, some organisations have started with Lean thinking and encourage systematic Lean systematic method to be implemented to assist their internal business process and to transform their organisations into more profitable, resource effective and even more reliable. Lean can be acknowledged as a quality improvement methodology that can identify and eliminate waste from process [2], [3]. Rooted in an automotive industry such as Toyota Production System, Lean production only required fewer resources to make a greater variety of products with fewer defects [4]. Besides the systematic method of Lean, technologies can also be adapted to improve the processes such as implementing an IT application to support Lean.

Patient-centred care has become one of the evolving trends and improving healthcare service is increasing in recent years [5]. Lean healthcare, from healthcare institutions such as hospital, in particular, exemplifies that member of the hospital can achieve a higher goal by acquiring fewer resources to produce fewer errors during working shift [4]. There are a few compelling factors in the healthcare industry (i.e., quality, efficiency, and cost), among others, and these factors are related to each other [6]–[8]. Controlling the cost is imperative in Lean, and this will improve the overall quality and efficiency.

In the literature, studies have shown the service industry such as hospital has moved into the implementation of IT applications as part of their Lean healthcare strategy and execution [9], [10]. These applications include Electronic Health Records, Computerized Clinical Documentation Systems and Health Information System to improve their operational processes in out-patients, in-patients, operation rooms and emergency areas [11], [12]. However, there is a lack of evidence about the implementation of specimen labelling and record system while this process is crucial in delivering general quality service to avoid defects (e.g., medication error and error in medication delivery) [13], [14].

Consecutively, one of the Malaysian hospitals through a dedicated team has taken an excellent initiative to introduce and adopt the Specimen Labelling System (SPLS) in one of its Lean Healthcare projects. The medical team and a group of researchers have established an efficient mechanism to implement a specimen handling system that can help to produce patient details on the specimen equipment, together with specimen dispatch report. The primary objectives of the SPLS are:

a. To reduce the time taken by medical staff to write patient information on sticker label;

b. To reduce the time taken by medical personnel to write specimen details on the specimen delivery report

Accordingly, reducing the time taken to write patient information is crucial to minimise error in handling patient specimen. While there is a high possibility of hospital staff will make a mistake during the specimen handling, the system should be able to eliminate manual effort and increase the productivity of the team. Furthermore, an efficient mechanism for producing specimen dispatch report is required to decrease patient waiting time while there are several patients in the queue.

The highlight of the current challenges is addressed to the stakeholders to adopt the SPLS, such as:

a. The stakeholders are ready to accept the changes in their work style by having this new system.
b. The hardware such as printers is available and ready to use in all pilot wards.
c. To ensure that the intranet/internet connection via cable is available at every station in all pilot ward.

The remainder of this paper is organised as follows: Section 2 explains the overall methodology used in the study. The methodology contains several approaches including requirement gathering, analysis and experimental setup. Section 3 focuses implementation and testing approach on testing the system against the requirements. Section 4 describes the experimental results using one of the common metrics of Lean evaluation. Section 5 concludes the results of the study and future research.

2. Research Methodology

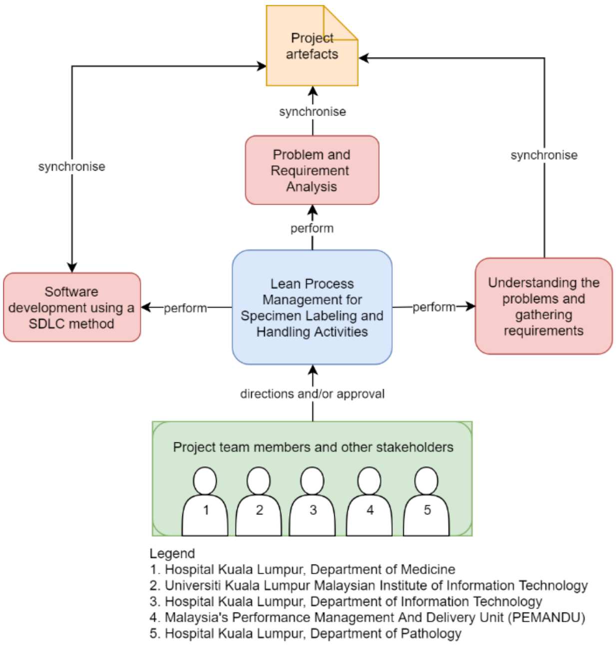

Fig. 1: SPLS research and project management plan

The study consists of various stages of information management. As shown in Figure 1, a holistic research methodology and project management plan, which contains disparate activities, is established as the protocol for conducting the study from various perspective. The stakeholder, which are of different interests, backgrounds, and operational tasks, is distinguished from providing supports such as the direction and approval of ideas where it is important in ensuring project success.

The management activities take information such as problems, raw requirements and statements as the input to the analysis process. While the raw information is usually unstructured by nature, some commonly used Software Engineering techniques are implemented to depict the system workflow and requirements. The techniques involved are selected based on the on-going focus-group discussions, meetings and observations. Documents are organised in parallel with the techniques for tracking and management purposes. The documents from these activities are prepared to guide the software development and other activities as they specified the system dependencies, objectives, specific system functions, and other requirements.

2.1. Understanding the Problems and Requirement Gathering

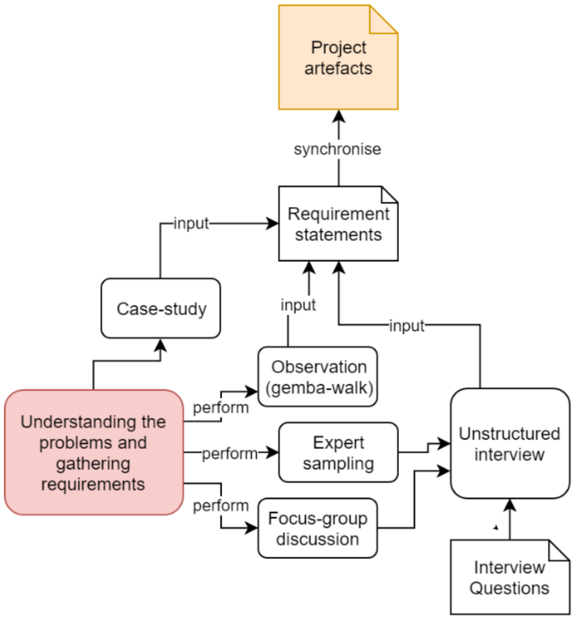

Fig. 2: Requirement gathering activities

Requirement gathering is the core activity before the development starts. As shown in Figure 2, several activities are done in ensuring problems and requirements are correctly gathered.

"Gemba Walk", a similar process of site observation, is one of the Lean activities used to observe the actual process, understand the process functions and observe the wasteful activities [15]. Sessions of unstructured interviews are scheduled to capture the requirements from the process owners. Expert sampling, a is a non-probability method, and purposive sampling is utilised to select several key persons with experience and expertise in the area of the study [16]. The activity is conducted to identify issues related to the owners' experiences while using the manual system. Based on the sampling method, three medical consultants, four medical officers, three matrons and four staff nurses are selected. Then, several groups of medical officers are gathered in split sessions to retrieve their statements. The questions focused on the users' experiences, struggles and problems in completing their specimen labelling tasks. Several case studies are selected as the research baseline to understand the processes and the existing system involved in the current manual specimen handling system. These activities are conducted to capture requirements and to design the "as-is" process.

The data collection period is executed throughout the project timeline. The site observation was performed in the first week of the project execution. Meanwhile, the unstructured interviews are conducted with an interval of one day. Both observation and unstructured interviews are performed during working hours from 8 a.m. to 5 p.m.

Based on the unstructured interviews and the observation, the "as-is" process and the actual time spent on each task in the process is identified. The problems are also defined:

a. First, the time taken to write patient particulars on sticker labels. The medical ward staffs in which they have to write the details on a label and paste the label on the specimen container. There are about six to twelve specimens upon admission.

b. Consequently, the staff has to manually write the labels depending on how many specimens are required. For an average of six specimens per patient per day, medical ward staff will take approximately 15 minutes to complete the tasks. For an average of a patient warded in the hospital for three days with an average of specimens taken per day, the medical staff will need to spend at least 45 minutes for each patient for writing on the labels.
c. Time taken to write and print specimen details in specimen delivery order. Medical ward staff needs to record the specimen information in the specimen delivery report manually. There will be an average of ten specimens for each delivery report. The medical ward staff will take an average of two minutes to record one specimen information in the delivery report. Therefore, the time spent to write down ten specimens' information for a delivery report is 20 minutes/report.

2.2. Deep Diving and Requirement Analysis

Raw requirements are generally given and written in an unstructured way. Deep diving the requirements and perform detail analysis is significantly important to encourage process improvements and reveal other opportunities. Figure 3 shows the process of analysing the raw requirements.

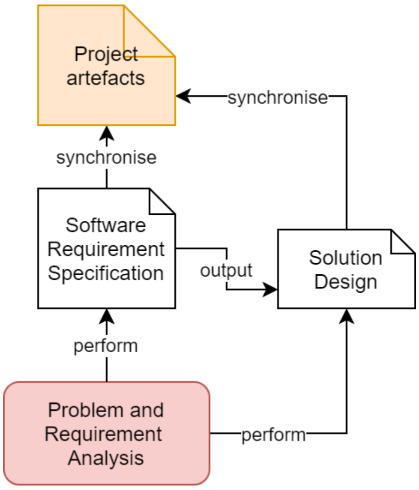

Fig. 3: Requirement Analysis Activities

The process takes raw requirements from previous activities to develop documents such as Software Requirement Specification (SRS) and Solution Design. The SRS mainly outlines the system functions, actors, and non-functional requirements. These highlights are useful to provide objectives and guidelines for the project team and developers, accordingly. The main objective is to build a web-based application that can be accessed through the web browsers from medical wards. The system is hosted on a PC that is physically placed in a dedicated data centre of the hospital. An authenticated user can access any readily available data to perform any functions. The solution is proposed in Figure 4 by considering the system scope and several connotations, including the Lean objectives, and quality.

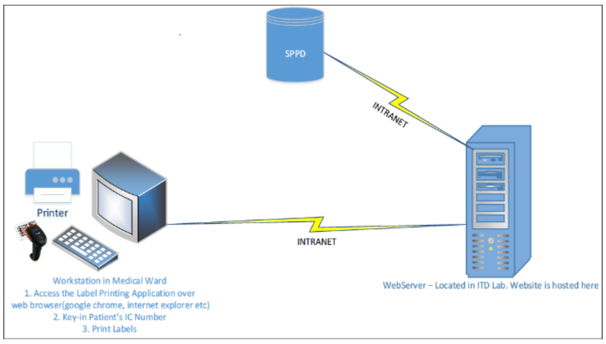

Fig. 4: Solution Design

The SPLS is developed based on the requirements captured and the solution design. The integration between the system and the existing database is established by implementing a web service, which it assists the barcode generation based on patient information. The barcode is crucial because it helps to reduce the time taken in writing information on the sticker label. Furthermore, the barcode information is also useful for another system.
Specifically, the development covers the following features:

a. Able to fetch details based on Identification Card (IC) number;
b. Able to generate barcode and print on the sticker paper;
c. Able to use the existing pre-cut sticker;
d. Able to update specimen to dispatch to the Pathology lab;
e. Able to print the specimen delivery report.

The "to be" process illustrated in Figure 5 is created by taking into consideration the wastes and problems in the "as is" process. The "to be" process was reviewed and validated by the process owners. The validation of the "to be" process was done by comparing the "as is" and "to be" process and the suggested solution.

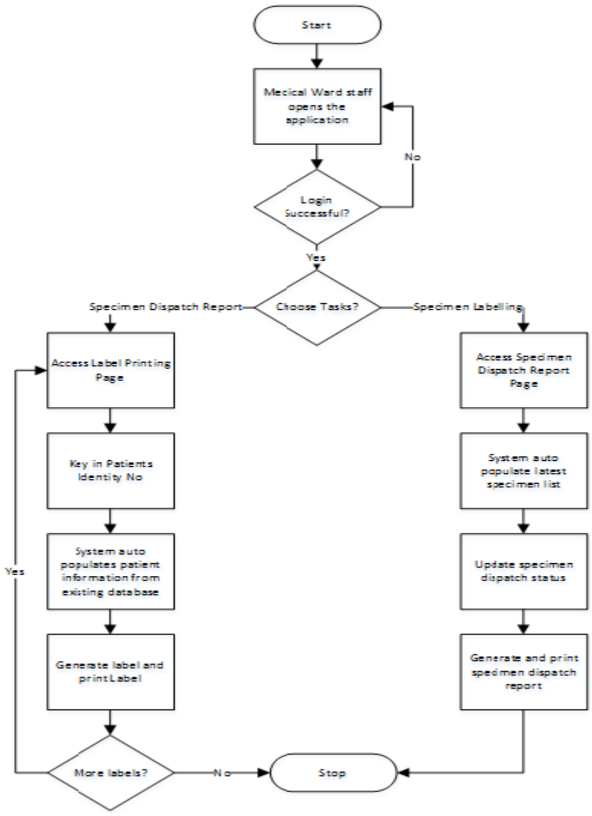

Fig. 5: System Process Flow

2.3. Prototype Development

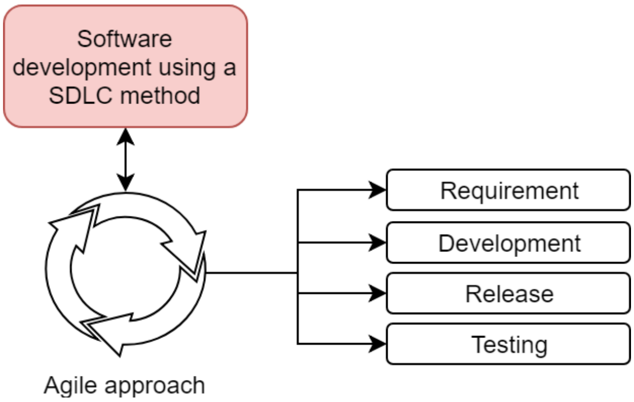

Fig. 6: Development activities based on the Agile development approach

An SDLC methodology called Agile is the incorporation of short cycles of planning and work to ensure adequate performance. This modular methodology has been acknowledged by an international standard of healthcare practice in achieving the goals of turnaround times and quality [17]. Subsequently, there is a study which attempts to combine agile methodology with Plan, Do, Study, Act (PDSA) cycle, a popular method to document a test of change in improving healthcare industry, to assist a robust improvement [18].

In this study, the Agile software development methodology is selected as shown in Figure 6, and the study is completed within two months. Meanwhile, Agile requirements engineering is also applied in requirements engineering stage to accelerate processes in the requirements stages such as elicitation, verification and validation of requirements.

In agile requirements engineering, the requirements are described gradually based on the interaction between the process owners and the development team, less formal and less documented [19]. The requirements engineering tasks such as elicitation, analysis, verification, validation and documentation are executed in parallel with development activities such as designing the technical solution and developing the solution. The same development team and process owners play a significant role to complete the tasks with high commitment and on schedule.

3. Implementation and Testing

While software testing is a validation approach in the development lifecycle and comprehends many activities, from unit testing to acceptance testing focus to achieve certain objectives [20], there are four types of testing conducted to examine the SPLS (i.e., hardware testing, integration testing, user acceptance testing (UAT), and performance testing).

Hardware testing is conducted to test the hardware, which involved a personal computer (PC), printer and barcode reader. The test is required to ensure the new and existing hardware is in the expected condition and conform with the requirements. Integration testing is another testing type to test the integration part of the new system and the current system. Particularly, it is to examine the data retrieval part from the existing database to the new system.

Pilot testing is conducted to test the system from various perspective. From three medical wards identified for the project, one ward is selected to start with pilot testing. Once the pilot testing completed, then the user acceptance testing (UAT) is executed on all identified wards. The UAT session for each ward is divided into two slots to accommodate their two working shifts, which are the morning shift and night shift. The sessions are conducted with the involvement of seven representatives from each ward, comprise of two medical officers, one Matron, one Sister and three staff nurses. Total users involved are 42 users.

Besides, the SPLS is also measured using one of the components in lean metrics. According to [21], [22], there are four components in lean metrics which are cost (financial performance improvement and cost reduction), time (waiting time reduction and length of stay reduction), defects (rework reduction and medical error reduction) and value (service capacity increase). Time is the selected component to be measured in this system, and it is tracked during the UAT session. Figure 7 and Figure 8 depicted two main pages of Specimen Label, and Specimen Dispatch developed and tested by the users in UAT sessions.

The Specimen Label page allows the medical staffs to print sticker labels and place them on any patient's related specimens including the follow-up card. The stickers are labelled by IC Number, name, ward, specimen name and barcode. The medical staffs are allowed to print the sticker labels based on the required quantity. The Specimen Dispatch page, on the other hand, allows the medical staffs to prepare and print the specimen dispatch report to be submitted to the Pathology lab. Based on the IC Number scanned from the sticker label, the staff is required to key in the specimen type which can be found in the physical specimen. Then, the specimen dispatch report will be printed according to the scheduled time, and the specimen dispatch status for each specimen must be updated before printing.

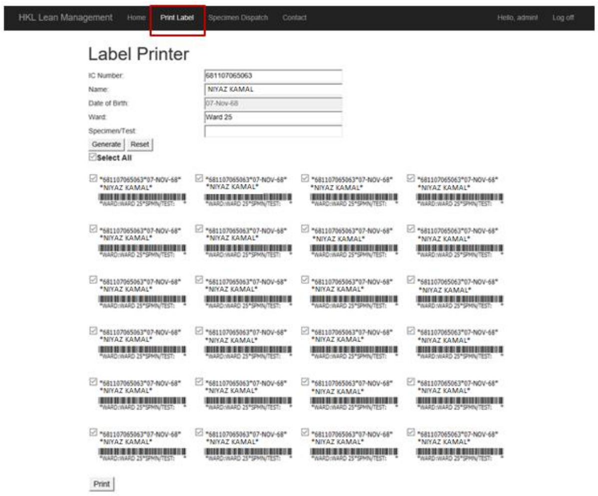

Fig. 7: Specimen Label

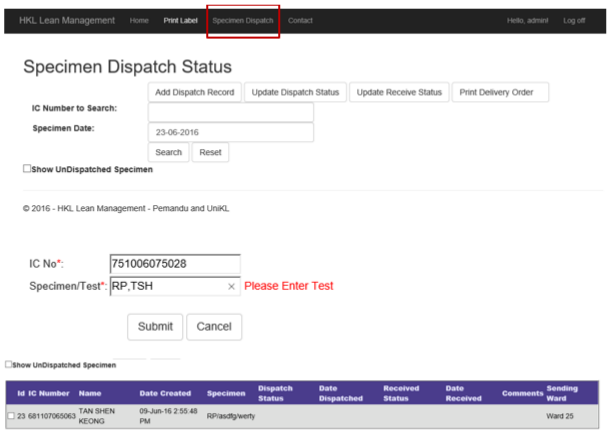

Fig. 8: Specimen Dispatch Page

4. Experimental Results

Table 1 lists the result of hardware testing, integration testing and UAT testing based on the test cases created for each of the features. The result is a pass for all the listed modules.

Table 1: System Testing Result

#	Test Area	Module	Result
1	Hardware Testing	PCs	Pass
		Printers	Pass
		Barcode Reader	Pass
2	Integration	Data retrieval	Pass
3	UAT	Fetch IC No	Pass
		Generate barcode	Pass
		Print to sticker	Pass
		Update specimen to dispatch	Pass
		Print specimen delivery report	Pass

Table 2 shows the result related to time, one of the lean metrics, conducted in three medical wards. The result indicates each user on average took not more than 5 minutes to complete specimen labelling task. This has shown that there is a tremendous improvement regarding the time required to complete specimen handling (i.e., labelling) which initially it takes around 45 minutes to complete.

Table 2: Task Completion Time (in minutes) for Specimen Labelling

User / Ward	Ward 1	Ward 2	Ward 3
1	5.4721	5.2547	4.8556
2	4.6124	5.1926	5.1646
3	4.6696	5.2436	5.0736
4	4.5750	4.9669	4.6361
5	5.0697	4.6640	5.3014
6	5.0066	5.0270	5.2254
7	4.9704	5.1248	4.5375
Average time	4.9108	5.0676	4.9706
Overall average time	4.9830		

On the other hand, Table 3 records the time taken for specimen dispatch report. Each user makes take up to 5 minutes to complete this task. These significant findings explain the system helps significantly to reduce the time taken off 20 minutes against the manual process.

Table 3: Task Completion Time (in minutes) for Specimen Dispatch Report

User / Ward	Ward 1	Ward 2	Ward 3
1	4.9548	4.7621	4.7794
2	5.155	5.3441	5.4961
3	5.1892	4.6144	5.3132
4	4.8164	5.0828	4.9251
5	5.4318	4.8148	4.8664
6	4.907	5.1901	5.2196
7	4.7039	4.8212	4.753
Average time	5.0226	4.9471	5.0504
Overall average time	4.9830		

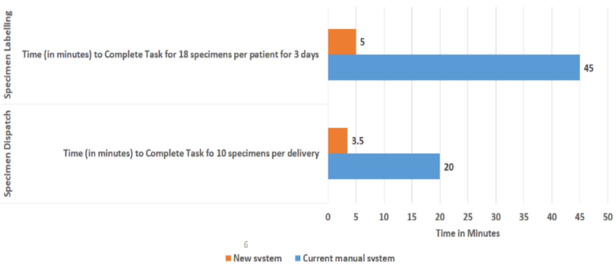

Fig. 9: Comparison of Task Completion Time between the existing system and the new system

Meanwhile, Figure 9 shows the overall results of comparing the task completion time between the existing system and the new system. The summary of the findings are as follows:

a. Specimen labelling:

It is found that time taken to write patient details is reduced from 45 minutes to almost 5 minutes.

i. The medical ward is required to enter the patient's IC Number only. Name and Date of Birth of the patient will automatically be displayed based on the Malaysian Identification (IC) Number.
ii. The medical ward staff then can start print the details on a sticker label.
iii. For an average of six specimens per patient per day, medical ward staff took about 5 minutes to print the label. The first printing consists of 24 sticker labels.
iv. For an average of patient warded in hospital for three days with an average of six specimens taken per day, only 18 sticker labels will be used out of 24 sticker labels.
v. Therefore, the time spent to print sticker labels is only 5 minutes and the printed sticker labels are sufficient for three days.

b. Specimen Dispatch report:

It is found that time taken to write and print specimen details in specimen delivery report are reduced from 20 minutes to 3.5 minutes.

i. With the system developed, the medical ward staff will be required to spend about 15 seconds to update one specimen information using a barcode scanner.
ii. Another 1 minute is required to update the specimen's dispatch status and print the delivery order.
iii. For an average of 10 specimens for each delivery:
iv. Time required for each delivery report = 10 specimens * 15 seconds + 1 minute = 3.5 minutes.

Additionally, it is also discovered that in Specimen Labelling, task completion time is reduced by 88.9%, and meanwhile, in Specimen Dispatch Report, task completion time is decreased by 82.5%. Based on the results, it can be concluded that the implementation of the Lean systematic method in SPLS for Lean Healthcare Project had successfully helped the staff to complete their tasks efficiently.

5. Conclusions

This case study evaluates the effectiveness of adopting the Lean process improvement methodology and the development of SPLS, a system to effectively produce labelling for the specimens and specimen delivery report in one of the Malaysian general hospitals. Agile requirement engineering and Agile development methodology are employed in this study to accelerate some development which these methods allow short cycles of planning and work to ensure adequate performance. Finally, in testing and experimental setup, the results indicated more than 80% reduction of time taken to complete the tasks.

The reduction of time is beneficial to the staffs and the management of the hospital wherein the extra time can be spent for other tasks. Moreover, it minimises the medication error and error in medication delivery and hence, allows the hospital to offer good quality healthcare service. Furthermore, system testing result shows a significant effect in which it reduces the average time to complete the tasks. Eventually, this will improve the overall quality and efficiency of service industry for public customers. The implementation of the Lean systematic method has moved the organisation from manual to an automated process using SPLS.

In the future, other areas of healthcare service such as patient physical record and appointment scheduling in the real hospital environment will be explored by adopting Lean system method to advance the existing (i.e., manual) process for quality improvement. Since the study examined only one component of overall Lean metrics, studies on other components are deemed useful. Moreover, the findings are worth for further exploration in patient and staff satisfaction in handling and receiving quality healthcare service.

Acknowledgement

The authors are thankful to the Hospital Kuala Lumpur (Malaysia) and the Malaysian Performance Management & Delivery Unit (PEMANDU) for the great teamwork and cooperation to make the Project a success. Many thanks to UniKL MIIT for the countless support.

References

[1] J. Bhamu and K. Singh Sangwan, “Lean manufacturing: literature review and research issues,” Int. J. Oper. Prod. Manag., vol. 34, no. 7, pp. 876–940, 2014.

[2] H. Hagg, D. Suskovich, J. Workman-germann, S. Scachitti, and B. Hudson, “Adaptation of Lean Methodologies for Healthcare Applications,” in Society for Health Systems Conference, 2007, no. 24.

[3] N. A. Khaidir, N. F. Habidin, N. Ali, N. A. Shazali, and N. H. Jamaludin, “Six Sigma Practices and Organizational Performance in Malaysian Healthcare Industry,” IOSR J. Bus. Manag., vol. 6, no. 5, pp. 29–37, 2013.

[4] B. B. Poksinska, M. Fialkowska-Filipek, and J. Engström, “Does Lean healthcare improve patient satisfaction? A mixed-method investigation into primary care,” BMJ Qual. Saf., vol. 26, no. 2, pp. 95–103, 2017.

[5] M. Mannon, “Lean Healthcare and Quality Management: The Experience of ThedaCare,” Qual. Manag. J., vol. 21, no. 1, pp. 7–10, 2014.

[6] A. M. Mosadeghrad, “Factors Influencing Healthcare Service Quality,” Int. J. Heal. Policy Manag., vol. 3, no. 2, pp. 77–89, 2014.

[7] S. J. Chang, H. C. Hsiao, L. H. Huang, and H. Chang, “Taiwan quality indicator project and hospital productivity growth,” Omega, vol. 39, no. 1, pp. 14–22, 2011.

[8] S. Robinson, Z. J. Radnor, N. Burgess, and C. Worthington, “SimLean: Utilising simulation in the implementation of lean in healthcare,” Eur. J. Oper. Res., vol. 219, no. 1, pp. 188–197, 2012.

[9] R. Agarwal, G. G. Gao, C. Desroches, and A. K. Jha, “Research Commentary—The Digital Transformation of Healthcare: Current Status and the Road Ahead,” Inf. Syst. Res., vol. 21, no. 4, pp. 796–809, 2010.

[10] M. Caldeira, A. Serrano, R. Quaresma, C. Pedron, and M. Romão, “International Journal of Information Management Information and communication technology adoption for business benefits : A case analysis of an integrated paperless system,” vol. 32, pp. 196–202, 2012.

[11] J. M. Goh, G. G. Gao, R. Agarwal, and J. M. Goh, “Evolving Work Routines : Adaptive Routinization of Information Technology in Healthcare,” Inf. Syst. Res., vol. 22, no. 3, pp. 565–585, 2011.

[12] J. Ker, Y. Wang, M. N. Hajli, J. Song, and C. W. Ker, “Deploying lean in healthcare: Evaluating information technology effectiveness in U.S. hospital pharmacies,” Int. J. Inf. Manage., vol. 34, no. 4, pp. 556–560, 2014.

[13] S. H. Haran, R. Ramlan, K. Ahmad, and A. A. Ahmad, “Value Stream Mapping Implementation in Healthcare: a Literature Review,” Soc. Sci., vol. 12, no. 6, pp. 977–983, 2017.

[14] T. J. Persoon, S. Zaleski, and J. Frerichs, “Improving preanalytic processes using the principles of lean production (Toyota Production System),” Am. J. Clin. Pathol., vol. 125, no. 1, pp. 16–25, 2006.

[15] G. Smith, A. Poteat-Godwin, L. M. Harrison, and G. D. Randolph, “Applying Lean Principles and Kaizen Rapid Improvement Events in Public Health Practice,” J. Public Heal. Manag. Pract., vol. 18, no. 1, pp. 52–54, 2012.

[16] I. Etikan, S. A. Musa, and R. S. Alkassim, “Comparison of Convenience Sampling and Purposive Sampling,” Am. J. Theor. Appl. Stat., vol. 5, no. 1, p. 1, 2016.

[17] C. Vilaplana Pérez, G. Soria Guerrero, F. Garriga Garzón, and A. Salas Garcia, “Lean-Agile Adaptations in Clinical Laboratory Accredited ISO 15189,” Appl. Sci., vol. 5, no. 4, pp. 1616–1638, 2015.

[18] S. J. Williams, “Delivering Agile and Person-centred Care,” in Improving Healthcare Operations: The Application of Lean, Agile and Leagility in Care Pathway Design, Springer, 2016, pp. 45–56.

[19] E. Bjarnason, K. Wnuk, and B. Regnell, “A Case Study on Benefits and Side-Effects of Agile Practices in Large-Scale Requirements Engineering,” in Proceedings of the 1st Workshop on Agile Requirements Engineering - AREW ’11, 2011, p. 3.

[20] A. Bertolino, A. Bertolino, and I. A. Faedo, “Software Testing Research : Achievements , Challenges , Dreams,” in Future of Software Engineering (FOSE ’07), 2007.

[21] A. Anvari, N. Zulkifli, and O. Arghish, “Application of a modified VIKOR method for decision-making problems in lean tool selection,” Int. J. Adv. Manuf. Technol., vol. 71, no. 5–8, pp. 829–841, 2014.

[22] L. B. M. Costa and M. Godinho Filho, “Lean healthcare: review, classification and analysis of literature,” Prod. Plan. Control, vol. 27, no. 10, pp. 823–836, 2016.